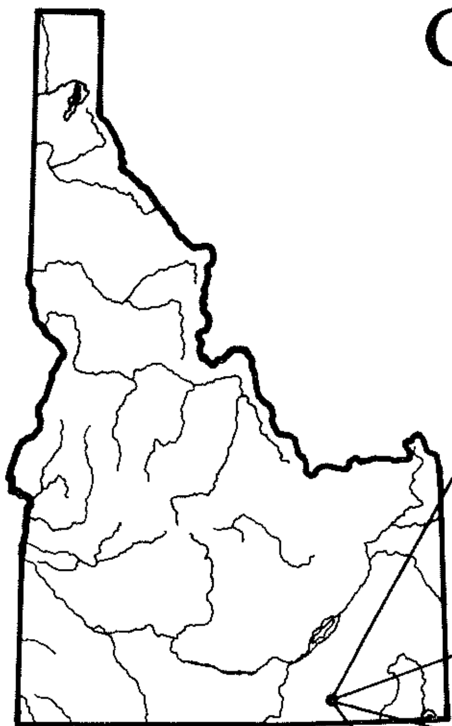
WATER RESOURCES

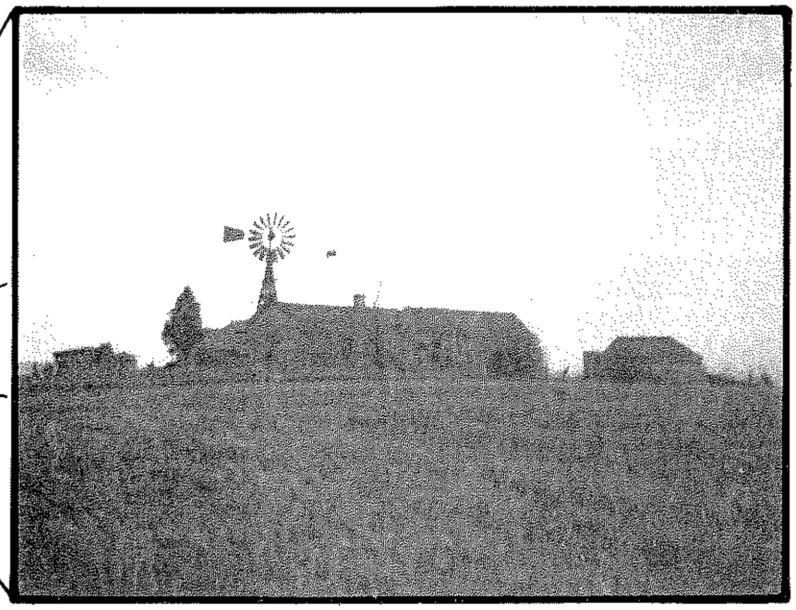
OF

WESTERN ONEIDA

AND

SOUTHERN POWER COUNTIES, IDAHO





IDAHO DEPARTMENT OF WATER ADMINISTRATION
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WATER RESOURCES OF WESTERN ONEIDA AND SOUTHERN POWER COUNTIES, IDAHO

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ABSTRACT

The study area, located in western Oneida, southern Power and eastern Cassia counties includes approximately 600,000 acres. All of it lies within the Basin and Range physiographic province. It is subdivided into four valleys: Curlew, Black Pine and Pocatello valleys which are within the Great Basin drainage, and Arbon Valley in the Snake River drainage.

The rock units in the area consist primarily of consolidated bedrock of Paleozoic limestone, dolomite, quartzite and sandstone, which are overlain by poorly consolidated sedimentary rocks of the Salt Lake Formation of Pliocene(?) age and by unconsolidated sediments of Pleistocene to Holocene age. The Salt Lake Formation and overlying sediments are the most productive and most commonly used aquifers.

Precipitation on the study area is the only source of recharge. Mean annual precipitation rates vary, primarily due to altitude changes, from a low of about 11 inches on the valley floor to nearly 30 inches on the highest peaks, averaging 15 to 16 inches for each valley. The total volume of precipitation falling on the study area is estimated at 510,000 acre-feet per year (ac-ft/yr). The portion of the precipitation available for diversion and use by man (water yield) is estimated to be 87,000 ac-ft/yr. The combined water yield of the Black Pine and Curlew subareas is approximately 59,000 ac-ft/yr, of which 53,000 ac-ft/yr is estimated to have flowed into Utah prior to pumpage of ground water for irrigation in the study area.

Surface-water supplies are important in the Curlew, Pocatello Valley and Arbon subareas. The flow of Deep Creek in the Curlew subarea primarily results from the discharge of Holbrook Springs located about two miles south of the village of Holbrook. The steady flow of 25-30 cubic feet per second (cfs) provided by these springs, along with runoff from the upper valley, is stored in Curlew reservoir for irrigation in the Stone, Idaho-Snowville, Utah area. Bannock Creek in the Arbon subarea is used within the study area for irrigation with an estimated 17,000 ac-ft/yr flowing out of the area. A flood pond forms during the spring runoff in the Pocatello Valley subarea which could be used for irrigation. The Black Pine subarea has no significant surface-water resource.

Well development has been primarily for domestic and stock use. The greatest irrigation well development has occurred in the Curlew subarea, with most of this development concentrated in the southern half of the valley. Pumpage from the aquifers of the Curlew subarea is estimated at 15,000 ac-ft/yr, but the actual consumptive use is probably about 6,000 ac-ft/yr. Some ground-water irrigation exists in Arbon Valley with the consumptive use being about 1,000 ac-ft/yr.

The water levels range from above land surface to 540 feet below land surface, but most wells on the valley floor have water levels less than 100 feet. Well productivity varies

widely and adequate data on well yields are missing in many areas. The most productive wells are located in the southern half of the Curlew subarea with specific capacities (Sc) of up to 100 gallons per minute per foot of drawdown (gpm/ft) reported. Well yields adequate for irrigation have been reported in the Curlew, Black Pine and Arbon subareas, but yields and pumping levels are unfavorable for irrigation well development in the Pocatello Valley subarea. No large seasonal or long-term declines in water levels have been observed in any of the subareas.

The quality of ground water is generally fair to poor. Values of specific electrical conductance (E.C.) ranging from 480 to 4,400 micromhos (umhos) have been measured. Water from 10 of 38 wells sampled does not meet U. S. Public Health drinking water standards. For irrigation purposes the ground water is not suitable for growing any but salt tolerant crops.

Some potential for additional irrigation development exists in each subarea. Development of ground-water supplies by wells in the southern part of Black Pine and Curlew subareas appears to be feasible. Some additional use of surface water could be made in Arbon and Curlew subareas if reservoir space were available. Development of the flood pond for irrigation in the Pocatello Valley subarea appears to be possible.

INTRODUCTION

OBJECTIVES

The Idaho Department of Water Administration has the responsibility for administering the use of the surface and ground waters of the State of Idaho to insure that the resource is fully utilized yet preserved for continued use in the future. This responsibility can be effectively met only if the Director of the department has thorough and modern knowledge of the water resources of the state. For this reason, he has authorized water resource studies of a number of areas in Idaho in which large-scale irrigation developments have taken place or a potential for such development exists. Although these studies are primarily intended to facilitate administration of water rights, the results also provide assistance to farmers, investors and others interested in developing water resources. The basic data generated by the study adds to the general knowledge of the resources of the state.

Surface-water supplies within this study area are essentially fully appropriated; yet thousands of acres of land suitable for irrigation are now dry cropped or used as dry rangeland. Some irrigation using ground water exists and the potential for more development appears good. However, it is probable that the study area, like other areas in southern Idaho, has more irrigable land than the available water supplies can adequately irrigate and unlimited development is not possible. This situation is emphasized by the administrative restriction to new development now applied to the Utah portions of two valleys which head within the study area. Extensive ground-water developments have been completed in the Utah portion of these valleys, and ground-water level declines in Utah have resulted in the closing of the area to approval of additional applications to appropriate ground water.

The large amount of irrigable lands which could be developed and the possibility of future water-level declines if this development occurs, make a study of the water resources desirable. Specifically, this study is designed to:

1. Determine the quantity of surface water and ground water within the study area that is available for development.

2. Estimate the quantity of surface water and ground water moving from Idaho into Utah in Black Pine and Curlew valleys.

3. Determine the geologic and hydrologic characteristics of the aquifers.

4. Determine the interrelationship between surface water and ground water.

5. Determine the quality of the ground water and its suitability for irrigation and domestic uses.

6. Tabulate the existing recorded water rights.

LOCATION AND EXTENT

The study area occupies approximately 940 square miles located in western Oneida, southern Power and eastern Cassia counties (fig. 1). It is bounded on the west by Black Pine Peak, the Sublett Range and the Deep Creek Mountains, on the south by the Utah-Idaho State Boundary, on the east by the Blue Spring Hills and the Bannock Range. The northern boundary is determined by the surface drainage divide between Starlight Creek and Moonshine Creek and the confluence of Rattlesnake Creek with Bannock Creek. The study area includes all of the Idaho portions of Pocatello, Curlew and Black Pine valleys and the southern (upper) portion of Arbon Valley. Black Pine and Curlew valleys are often described as being arms of the single Curlew Valley which extends southward into Utah as a portion of the Great Salt Lake drainage basin. For this study, however, the valleys are considered as separate subareas (fig. 1). The Pocatello Valley subarea is a closed topographic basin, but is ordinarily considered to be part of the Great Basin drainage. The Arbon subarea is part of the Snake River drainage.

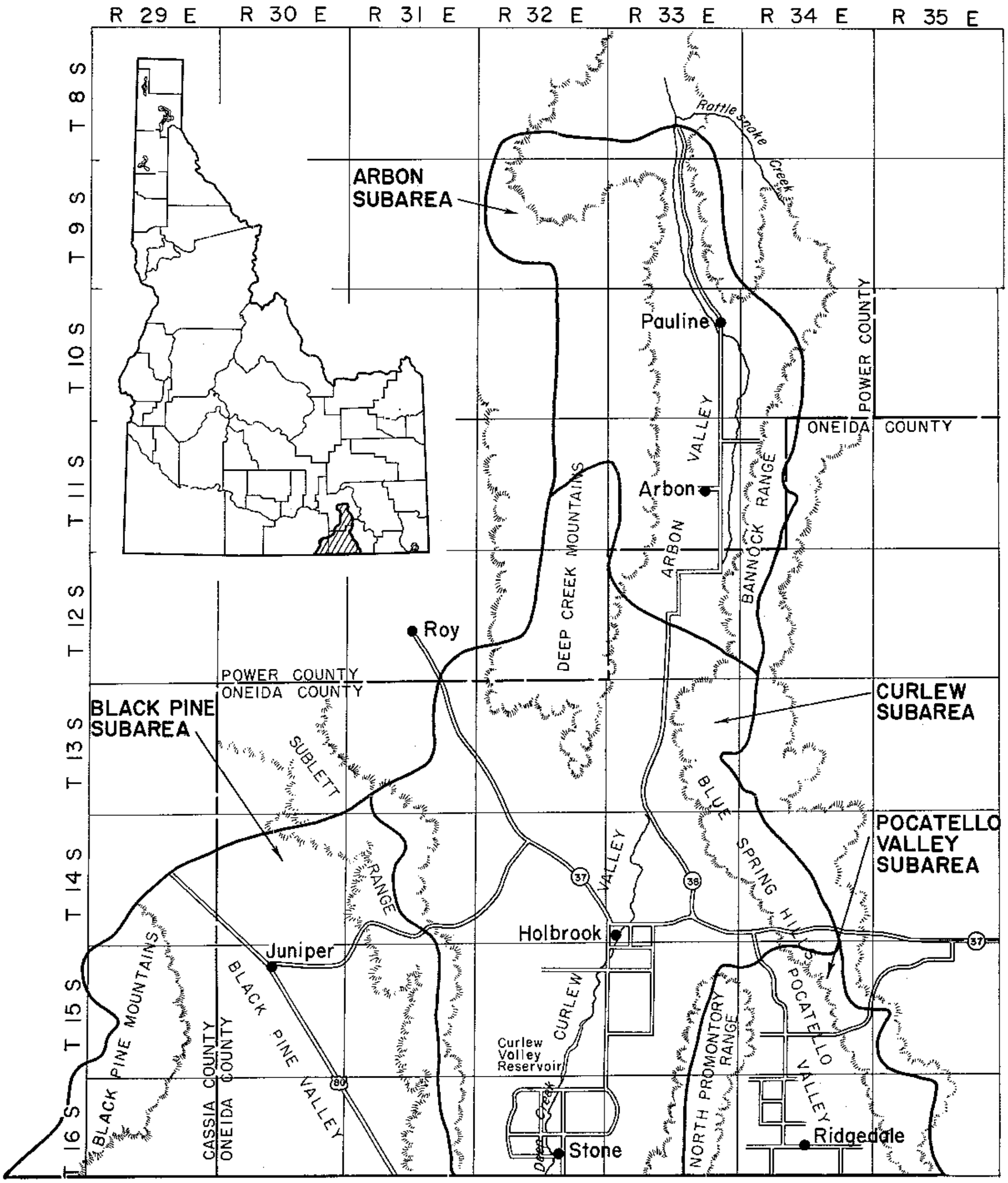

FIGURE 1. Location and extent of study area and delineation of the subareas.

METHODS

The field work was conducted during the period March to November, 1970. Data on the geology of the area were obtained by field examination of geologic formations, down-hole geophysical logging of selected wells and by review of published reports. All wells were inventoried and monthly observations of water levels were made in 38 selected wells. Additional data on the ground-water system were obtained by operating continuous water-level recorders on four wells. The elevations of the measuring point on 67 wells in the study area were established by spirit leveling. Data on surface-water flow were obtained from several discharge measurements on Deep Creek, Bannock Creek, irrigation canals and from records of the U. S. Geological Survey (USGS). Ground-water samples were collected on 15 wells and miscellaneous measurements of specific electrical conductance and temperature were made on many others to provide data on the chemical quality of water.

PREVIOUS INVESTIGATIONS

Detailed studies of the hydrology of the entire study area have not been made previously. Earlier studies of the area have been limited to cataloguing wells and springs, or data have been included only incidentally to investigations of adjacent areas. The USGS completed an inventory of wells and springs in the Curlew, Black Pine and Pocatello valleys during 1947 and 1948 (Nace, 1952). In addition to data such as location, physical description and depth-to-water for each well, Nace's report also includes chemical quality data for water from selected wells.

In 1931, the USGS in cooperation with the Idaho Department of Reclamation completed a survey of the water resources of Curlew Valley in connection with a more detailed study of Malad Valley (Thompson and Faris, 1932). Included in the 1932 report and a supplement are data on ground-water development, a detailed well inventory including elevation of the land surface at 54 wells and a brief description of the surface-water hydrology of the Curlew subarea.

A recent reconnaissance-level hydrologic study made by the USGS in cooperation with the Utah Department of Natural Resources (Bolke and Price, 1969) provides an estimate of water yield from Curlew and Black Pine valleys as it affects recharge to the Utah portion of these valleys. The report also includes some data on ground-water movement.

The only published data on the hydrology of the Arbon subarea are included in studies of potential reservoir sites (U. S. Bureau of Reclamation and U. S. Army Corps of Engineers, 1952 and U. S. Army Corps of Engineers, 1948). These reports outline the physical characteristics of the subarea and provide an estimate of water yield.

Reports pertaining to the geology of the area have been aimed primarily at the petroleum potential in the rocks of Paleozoic age. Anderson (1931) published a report summarizing the geology and mineral resources of eastern Cassia County. Piper (1924) analyzed the potential for petroleum in Power and Oneida counties. Both publications dwelled heavily upon the Paleozoic rocks which form the mountain ranges surrounding the area. Other investigations concerning the encroachment of Lake Bonneville into the study area have been completed. The latest and most complete of these was conducted by Bright (1963).

WELL-NUMBERING SYSTEM

The well-numbering system used in this study is the same as that used by the USGS elsewhere in Idaho. This system indicates the locations of wells within the official rectangular subdivisions of the public lands with reference to the Boise base line and meridian. The first two segments of a well number designate the township and range. The third segment gives the section number, followed by two letters and a numeral which indicate the quarter section, the forty-acre tract, and the serial number of the well within the tract. Where possible, a third letter is added to denote the ten-acre tract included within the forty-acre tract. Quarter sections are lettered a, b, c and d in counterclockwise order from the northeast quarter of each section (fig. 2). Within the quarter sections, forty-acre tracts and ten-acre tracts are lettered in the same manner. For example, well 16S 32E 27daa1 is in the NE¼ of the NE¼ of the SE¼ of Section 27, Township 16 South, Range 32 East and is the first well designated in that tract.

GEOGRAPHIC SETTING

The study area in western Oneida County is in the Basin and Range physiographic province. It is characterized by high, steep-sided mountain ranges which trend in a north-south direction. The elevation ranges from 4,558 feet in Curlew Valley to 9,385 feet above mean sea level at Black Pine Peak.

Drainage in Curlew Valley is primarily from Deep Creek, a perennial stream. Numerous small, ephemeral streams issue from side canyons but contribute little to Deep Creek except during spring runoff. Black Pine Valley contains no perennial streams. All water issuing from drainages along the mountain front sinks into the ground without traveling a significant distance. Arbon Valley has only two perennial streams, Bannock Creek and Rattlesnake Creek. Bannock Creek drains the lower portions of the valley and Rattlesnake Creek flows along the northern boundary of the area investigated. Drainage in Pocatello Valley occurs from numerous small, ephemeral streams. Because the valley is a closed basin, spring runoff forms a large pond in the center of the valley, which usually disappears about May of each year.

Sagebrush and rabbit brush are the dominant native lowland vegetation with conifers and juniper occurring at higher elevations. Crops in Pocatello and Black Pine valleys are all dryland grains. Arbon Valley contains some irrigated grain and alfalfa, but dryland grain is

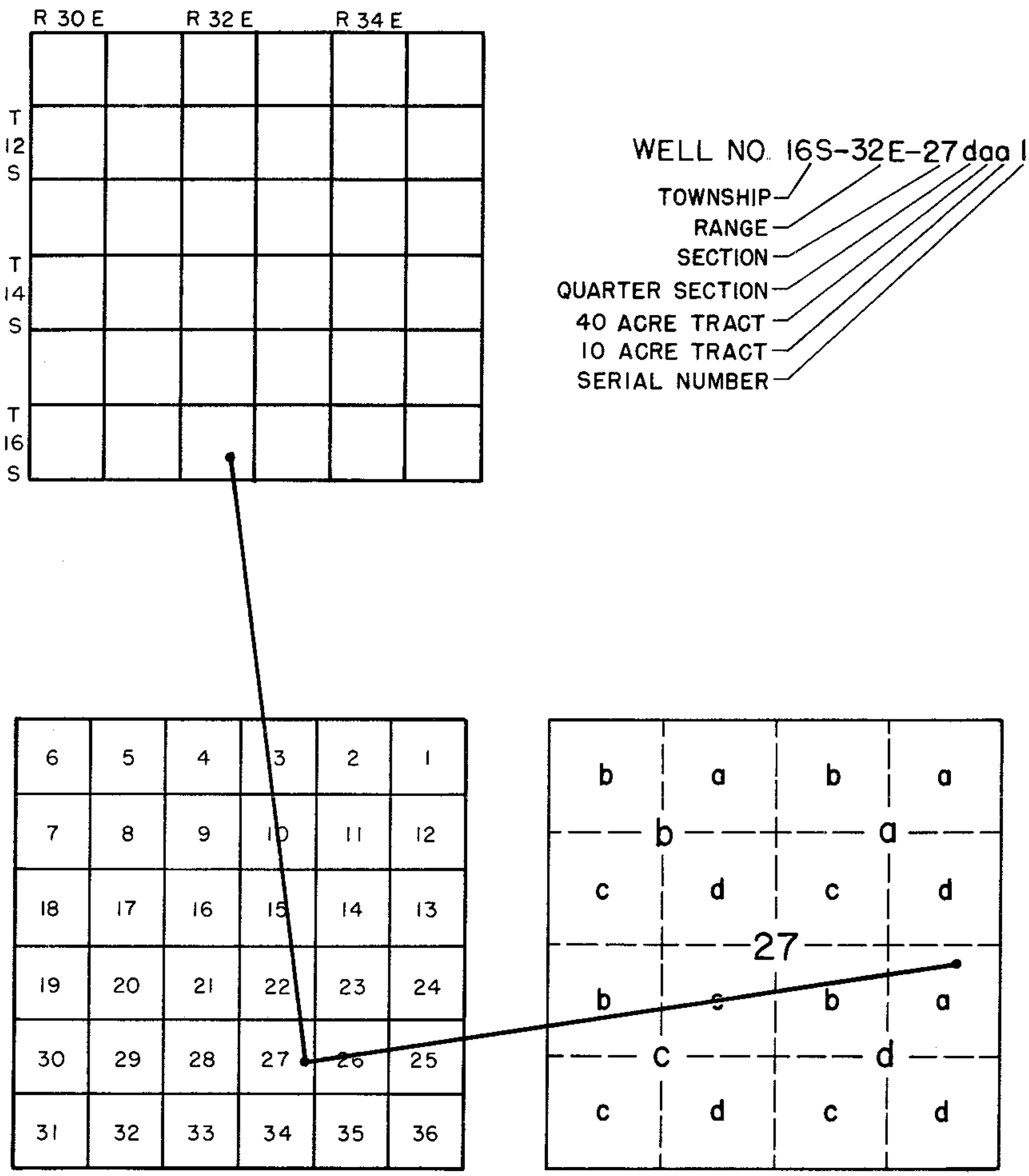

FIGURE 2. Well-numbering system.

the dominant crop for most of the valley. Curlew Valley is the only one in the study area that contains large expanses of irrigated acreage. Crops grown by irrigation include alfalfa, cereal grains, pasture and seed potatoes.

CLIMATE

The climate of the study area varies from semi-arid on the valley floors to subhumid at higher elevations. Records of climatic variations are available at very few locations. The only National Weather Service (NWS) station within the study area is located at the Arbon Post Office, and has been in operation since 1962. Most climatic variations must be inferred from stations outside of the study area. Precipitation and temperature data for stations with conditions similar to those at the lower elevations within the study area are listed in table 1. These data indicate that the average precipitation is approximately 10 to 12 inches and the average annual temperature is approximately 45^{o}-46^{o} Fahrenheit (F).

Short-term precipitation records for storage gages at higher elevations located near the study area are listed in table 2. As can be readily seen from table 2, the annual precipitation increases rapidly with elevation. Black Pine Canyon station has the highest annual precipitation of all measured stations of 21.6 inches. For higher elevations which have not been gaged it is estimated that the average rate of precipitation exceeds 30 inches per year.

The length of the growing season also varies with elevation. At Snowville, Utah, located just south of the Curlew subarea, the average period between the last 28^{o} F temperature and the first 28^{o} F temperature of fall is 122 days (Bolke and Price, 1969). This period is probably indicative of the growing season in the lower areas of each valley, but the growing season decreases with increased elevation.

Records of other elements of climate, such as humidity, wind direction and velocity, evaporation and solar radiation are not available for the study area.

ACKNOWLEDGEMENTS

The Department of Water Administration and the authors wish to acknowledge the assistance of Claude Baker of the Utah District office of the U. S. Geological Survey in sharing information on the study area. The Idaho District office of the USGS provided surface and down-hole geophysical data which aided in interpretations of portions of the study area. The Snake River Development office of the U. S. Bureau of Reclamation performed the chemical analyses of water samples. The Utah Power and Light Company provided information on power consumption in the operation of irrigation wells in the area and supplied power to operate the pump for the aquifer test performed during the study. The cooperation of the many well drillers, tenants and owners who supplied information and allowed access to their wells is also gratefully acknowledged. A special note of gratitude

Table 1

Mean Monthly Precipitation and Temperature at National Weather Service Stations

in and adjacent to the Western Oneida County Study Area

Station	Arbon		Kelton, Utah		Malad		Snowville, Utah		Strevell		American Falls		Malta	
Elevation	5170		4224		4420		4530		5290		4318		4540	
Years of Record	8	8	51	25	49	46	53	63	26	24	64	54	7	6
Latest Year of Record Used	1970	1970	1966	1929	1960	1960	1966	1966	1968	1968	1960	1960	1969	1969
Month	(in.) Precip.	(°F) Temp.	(in.) Precip.	(°F) Temp.	(in.) Precip.	(°F) Temp.	(in.) Precip.	(°F) Temp.	(in.) Precip.	(°F) Temp.	(in.) Precip.	(°F) Temp.	(in.) Precip.	(°F) Temp.
January	1.74	23.3	.67	22	1.44	22.3	1.13	22	.62	22.2	1.29	23.9	.45	28.4
February	1.41	29.9	.64	28	1.30	27.3	0.85	27	.62	25.8	1.00	28.2	.39	30.7
March	0.89	31.9	.52	38	1.23	35.4	1.17	35	.78	34.0	1.20	35.9	.26	35.4
April	1.39	41.0	.62	45	1.38	45.7	1.24	44	1.20	44.1	1.18	45.8	1.08	41.4
May	1.34	52.1	.76	54	1.40	54.4	1.60	52	1.62	52.0	1.46	54.1	1.56	51.3
June	2.33	57.9	.51	64	1.12	62.0	0.97	60	1.40	62.6	0.99	61.7	1.75	58.5
July	0.81	67.9	.41	71	.84	70.7	0.50	69	0.71	70.0	0.55	70.4	0.68	68.0
August	1.00	65.8	.29	70	.94	68.7	0.58	68	0.97	67.7	0.52	68.8	1.45	65.0
September	0.63	50.4	.51	58	1.02	59.6	0.71	57	0.75	60.1	0.65	59.1	.25	56.8
October	0.73	46.9	.57	49	1.17	48.4	0.95	46	0.88	47.3	1.09	47.9	.50	48.2
November	1.49	34.9	.43	35	1.20	35.2	1.01	35	0.77	33.7	1.08	35.4	.81	37.6
December	2.41	23.5	.70	24	1.39	26.2	1.07	24	0.71	25.6	0.99	26.7	1.13	26.5
Annual Precipitation	16.17	-	6.63	-	14.43	-	11.78	-	11.03	-	12.00	-	10.31	
Average	-	44	-	46	-	46.3	-	45	-	45.4	-	46.5	-	45.7

Table 2

Precipitation Records from Storage Gages Near the Western Oneida County Study Area

(Records collected by U. S. National Weather Service, except as noted.)

Station	Location	Period of Record	Altitude Ft. above MSL	Approx. Annual Precipitation (inches)
Black Pine Canyon *	Sec. 29, Twp. 15 S Rge. 29 E	1965-67	7,100	21.6
Gunnell Guard Station	Sec. 16, Twp. 15 S Rge. 28 E	1961-69	5,880	14.6
Dry Creek Flat	Sec. 35, Twp. 13 S Rge. 37 E	1966-69	6,350	18.3
Sublett Guard Station	Sec. 9, Twp. 12 S Rge. 30 E	1961-69	5,800	20.9

* Station operated by U. S. Geological Survey.

is extended to Blaine and Earl Hickman for allowing their irrigation well to be pumped for the aquifer test.

GEOLOGIC FRAMEWORK

STRATIGRAPHY

The rock units may be subdivided into two basic classes: consolidated or bedrock and unconsolidated sediments. These rocks are delineated in table 3 and figure 3. The consolidated rocks form the mountains and hills and consist chiefly of Paleozoic limestone, dolomite, quartzite and sandstone. These rocks are highly cemented and most do not readily transmit ground water. The limestones and dolomites may transmit some ground water in solution cavities formed by dissolution of the calcium carbonate in the rock along bedding planes and joints. The quantity of the ground water moving through these rocks is considered to be small. Basaltic volcanic rocks of tertiary age are present in Curlew Valley northwest of Holbrook. These volcanics are fresh appearing and are well jointed but at most locations lie above the regional water table. Locally springs issue from crevices in the basalt, the largest of these being Rock Springs which discharges an estimated 50 gpm during the summer months. Poorly consolidated sedimentary rocks are exposed along the margins of Curlew and Black Pine valleys. These rocks of the Salt Lake Formation are composed of

Table 3

Geologic Units and their Hydrologic Properties in the Western Oneida County Study Area

GEOLOGIC TIME				SYMBOL	GEOLOGIC CHARACTERISTICS	HYDROLOGIC CHARACTERISTICS
YOUNGEST	CENOZOIC	Quaternary	Holocene	Qal	Colluvium and alluvium along streams and fans. Consists chiefly of sand, silt and gravel derived from Paleozoic source areas	Very permeable materials at most locations. The majority of the wells appear to be finished in those deposits. High yield-to-wells are common
			Pleistocene	Ql	Lakeshore deposits of sand and gravel in bars and lake terraces.	Generally above the water table in the study area The deposits transmit recharge to underlying formations well.
		Tertiary		Qtb	Basaltic or andesitic volcanic rocks present near Holbrook.	Permeability of the basalt is generally high. In Idaho the basalt usually lies above the regional water table but facilitates recharge to the underlying formations. Several springs issue from these rocks.
				Isr	Continental sedimentary rocks including the Salt Lake formation. Chiefly composed of shale, tuff, sandstone, conglomerate, with some volcanic rocks.	Permeability varies widely within the study area. Where coarse sediments are present yield-to-wells is often high.
OLDEST	MESOZOIC	Triassic – Cretaceous			Mesozoic rocks are not present within the boundaries of the study area	
	PALEOZOIC	Cambrian – Permian		Pal	Primarily limestone, dolomite, quartzite, sandstone and shale. Highly indurated with some low grade metamorphism	Permeability is generally low due to the degree of cementation and metamorphism. Secondary permeability exists where solution cavities have been formed in the calcareous rocks or where fractured or brecciated zones exist near faults

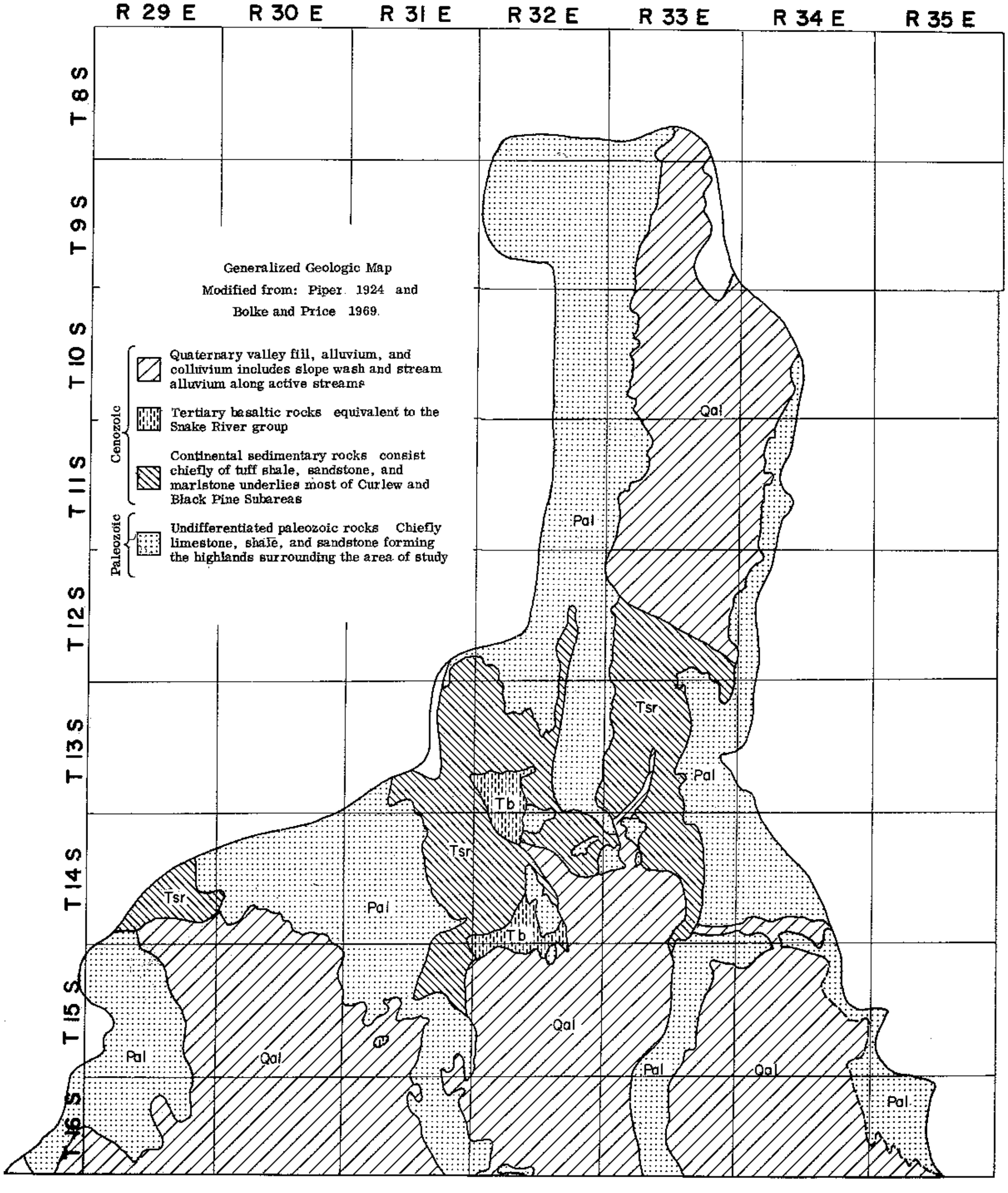

FIGURE 3. Generalized geologic map of the western Oneida County study area.

light colored clay, silt and sand from terrestrial sources. The formation is utilized as an aquifer in the valleys, but it is difficult to distinguish it from the overlying unconsolidated sediments.

Unconsolidated sediments overlie the Salt Lake Formation in Curlew and Black Pine valleys and form a thick fill in Arbon and Pocatello valleys. These sediments are composed of calcareous silt, sand and gravel originating from the mountains rimming these valleys. Because of the closed topography of Pocatello Valley, sediments are generally finer grained there than in the other subareas. The unconsolidated sediments are believed to be the source of water for most of the wells. All of the irrigation wells derive water from sand and gravel in the uppermost part of the valley fill.

Beach gravels and terrace deposits of Pleistocene age are exposed on the flanks of Curlew and Black Pine valleys. These deposits were emplaced during the higher stages of the ancient Lake Bonneville, which filled the valleys to approximately 5,100 feet elevation (Bright, 1963). At lower elevations lenses of residual salts have been deposited in the valley fill. These were deposited after Lake Bonneville receded and left numerous ponds of saline water. The deposits directly affect the quality of the ground water in these subareas.

STRUCTURE

The study area lies entirely within the Basin and Range physiographic province. This province was formed when compressive forces folded and faulted the Paleozoic rocks. This folding resulted in great mountain ranges and valleys being created with their axes lying in a north-south direction. Geophysical evidence indicates that the Paleozoic rocks may be more than 5,000 feet below the present valley floor of Curlew Valley and more than 4,000 feet below the Black Pine Valley floor. This indicates that low density materials, the Salt Lake Formation and valley fill attain 4,000 to 5,000 feet of thickness in these valleys. It is believed that the bedrock on the east side of Curlew Valley slopes quite gently toward the center of the valley while the west side drops rapidly. Because of the lacustrine environment during the later stages of deposition and the gentle slope of the underlying bedrock, finer grained sediments were deposited on the east side of the valley. This is believed to be the reason for the low well yields found for some wells in Township 16 South, Range 33 East.

No data are available to determine the thickness of the sediments in Pocatello Valley. Wells have been drilled to over 300 feet in depth near the center of the valley but none have been reported encountering bedrock. An exploratory gas well (10S 33E 35dcc1) was drilled in 1969 in Arbon Valley to a depth of about 3,670 feet. It is estimated that approximately 3,000 feet of the well are in valley fill sediments or the equivalent of the Salt Lake Formation (Crosthwaite, written comm., 1971). Data are not available to determine if this is the maximum thickness of the sediments in this valley.

WATER RESOURCES

VOLUME OF PRECIPITATION

The distribution of precipitation must be estimated by empirical methods because adequate records are not available. An isohyetal map (fig. 4) was developed based upon the most recent estimate of the relationship between precipitation and altitude (fig. 5). Several other isohyetal maps are available but were developed prior to the collection of the short-term records for the higher elevations (table 2). These records indicate that precipitation does not increase as rapidly with elevation as the previous isohyetal maps indicate. The ishyoetal map used in this report was developed without consideration of changes in precipitation caused by regional storm patterns or rain shadows caused by local topography.

The volume of precipitation for each subarea was determined from the isohyetal map (fig. 4) by summing the product of the planimetered area between isohyets and the average value of the bounding isohyets. The volume of mean annual precipitation as determined by this method is presented for each basin in the following table:

Table 4

Volume of Precipitation for the Western Oneida County Study Subareas

Subarea	Area (rounded) (acres)	Precipitation Volume (rounded) (ac-ft/yr)	Average Precipitation Rate (inches/yr)
Arbon	145,000	200,000	16.5
Black Pine	150,000	190,000	15.2
Curlew	250,000	320,000	15.3
Pocatello	55,000	70,000	15.3

The combined volume of precipitation on Curlew and Black Pine valleys is 510,000 ac-ft/yr. For comparison, a value of 536,000 ac-ft/yr was estimated by USGS investigators for this same area using an isohyetal map prepared by the NWS River Forecast Center, Portland, Oregon (Bolke and Price, 1969, p. 12-13).

WATER YIELD

Most of the precipitation which falls on the study area is returned to the atmosphere without first entering streams or aquifers. The water yield of a basin, that part of the water resource that is potentially available for use by man, is the portion of precipitation not evapotranspired by native vegetation (Walker & others, 1970, p. 33). A number of methods

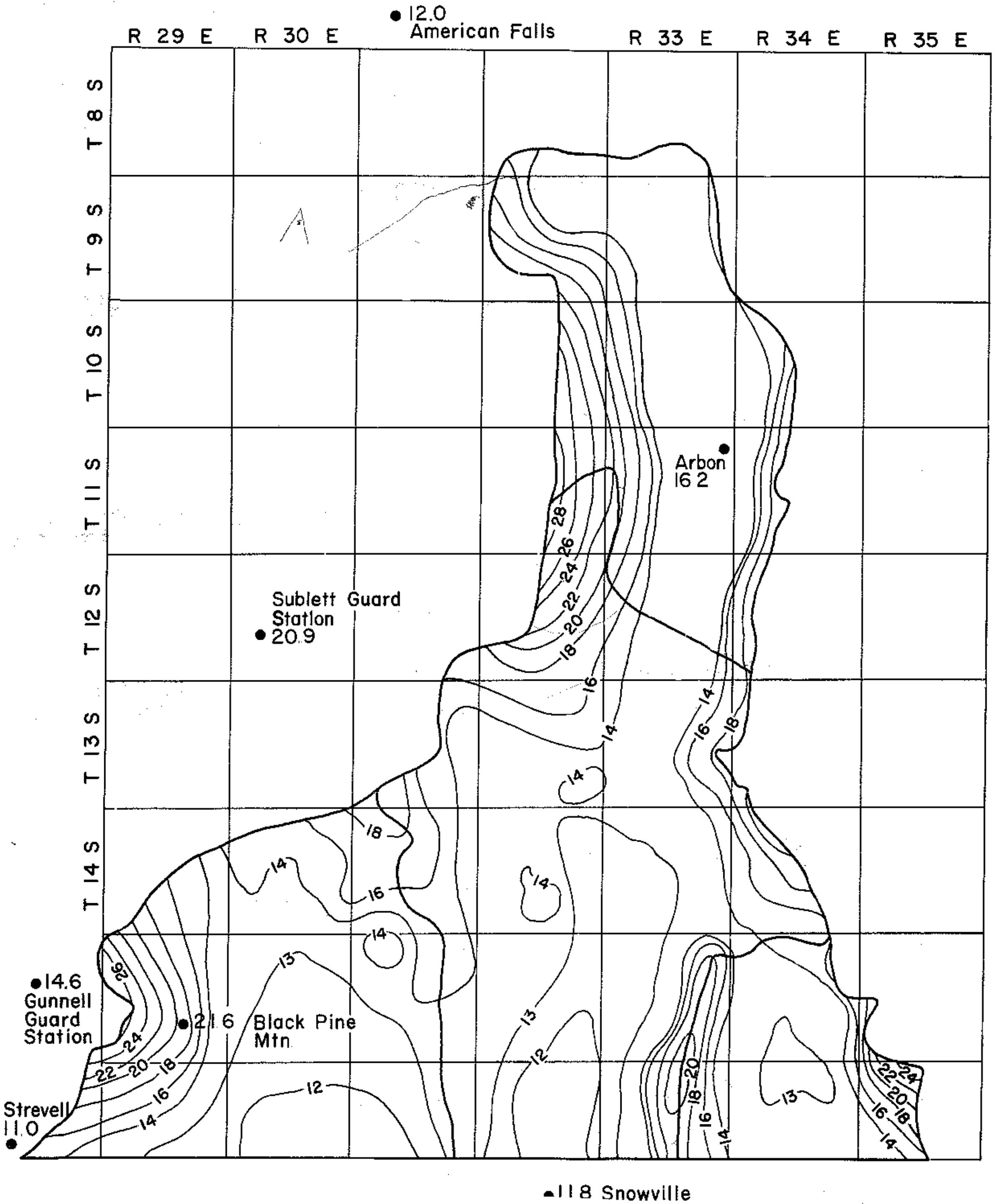

FIGURE 4. Isohyetal map of the western Oneida County study area.

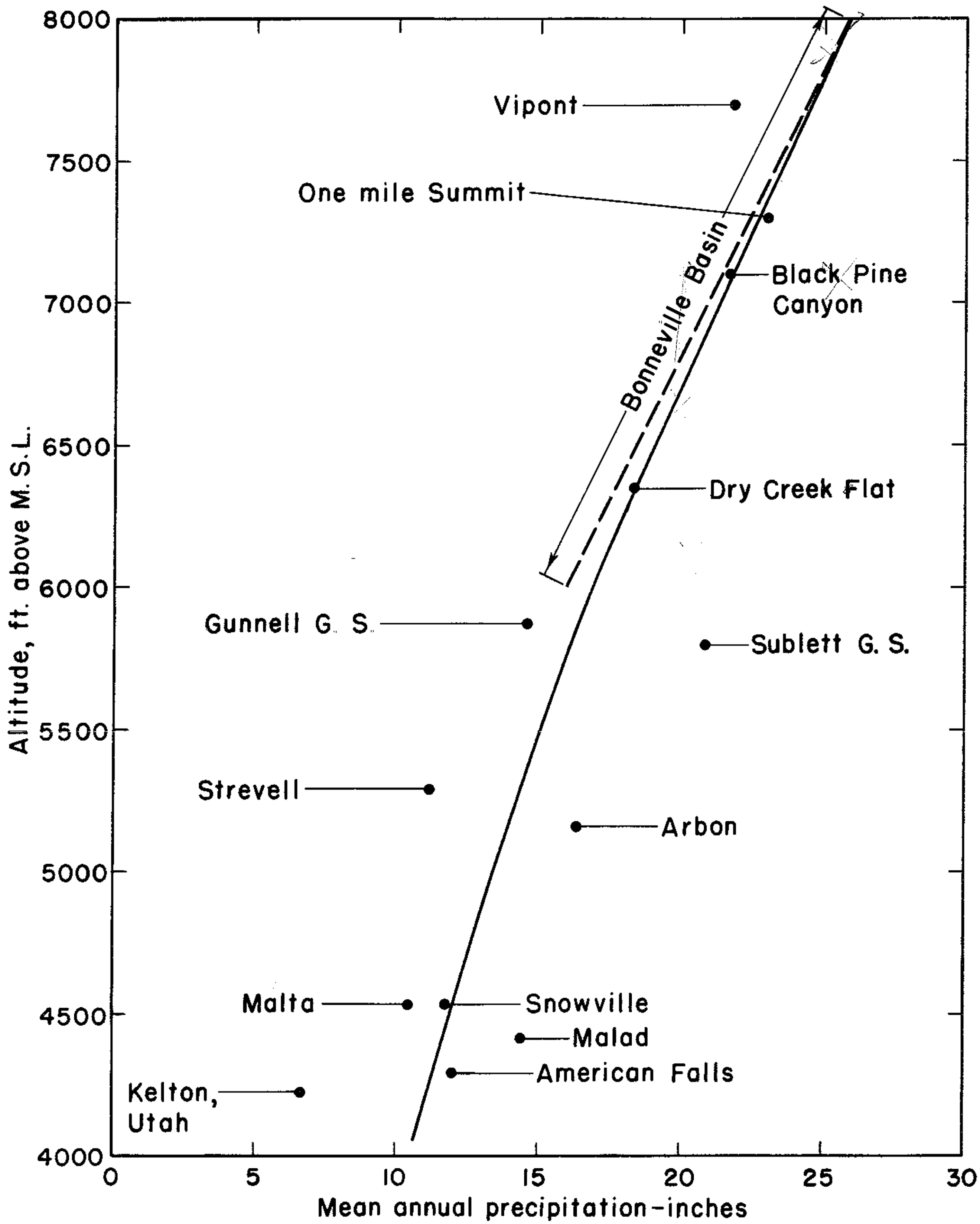

FIGURE 5. Relationship of precipitation and altitude for stations in and near the western Oneida County study area.

have been developed for estimating water yield. The inadequate amount of climatic data available for the study area makes it impractical to determine water yield by the direct method suggested by the definition. The amount of evapotranspiration that actually occurs depends not only on climatic factors, but also on the availability of moisture for evapotranspiration at the time favorable conditions occur. Because data are not available to make a reliable estimate of actual evapotranspiration, the estimates of water yield were made using an empirical method developed by W. B. Langbein (Nace and others, 1961, p. 36-47). The method utilizes a relationship between precipitation, potential evapotranspiration and water yield developed from data for basins in which the entire water yield can be measured as surface runoff (fig. 6). When using this method, it is assumed that the same relationships apply to basins for which part of the water yield leaves the the basin as ground water.

Average annual water yield was computed for each of several altitude zones as shown in table 5. For each altitude zone (column 1), a mean annual precipitation (column 2) was determined from figure 5 and a mean annual temperature (column 3) was obtained from figure 7. Potential evapotranspiration (column 4) for this altitude was determined from figure 8. The relationship between annual temperature and potential evapotranspiration shown in figure 8 was developed from differences between measured precipitation and runoff in humid regions in which potential evapotranspiration and actual evapotranspiration are essentially equal. The ratio of precipitation (P) to potential evapotranspiration (L) (column 5) was used to determine the ratio of water yield (R) to potential evapotranspiration (L) (column 6) using figure 6. The average annual water yield for each altitude is then determined as the product of the corresponding values in columns 4 and 6.

Table 5

Summary of Calculation of Water Yield as a Function of Altitude in the

Western Oneida - South Power Counties Area *

Altitude (feet) 1	Mean Annual Precipitation (P) (inches) 2	Mean Annual Temperature (°F) 3	Mean Annual Potential Evapo-transpiration (inches)(L) 4	Ratio P/L 5	Ratio R/L 6	Mean Annual Water Yield (R) (inches) 7
8,000	26.0	35	15	1.73	0.79	11.9
7,000	21.4	38	17.5	1.22	0.33	5.8
6,000	17.0	41	19	0.89	0.12	2.3
5,000	13.5	44.3	21	0.64	0.027	0.57
4,500	12.0	46	22	0.54	0.014	0.31

* Calculations adopted from a method developed by W. B. Langbein (Nace and others, 1961).

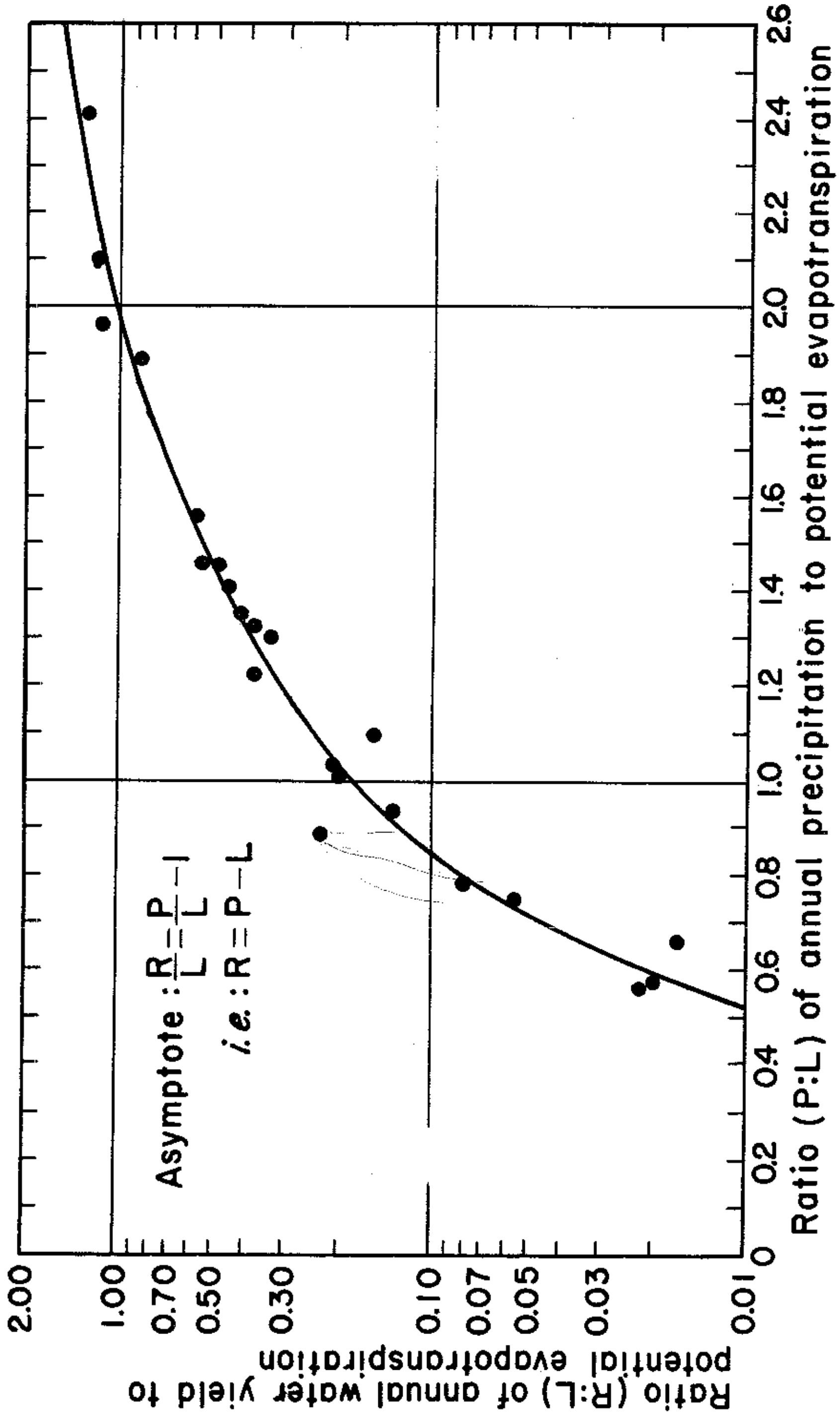

FIGURE 6. Relationship of annual water yield to precipitation and potential evapotranspiration.

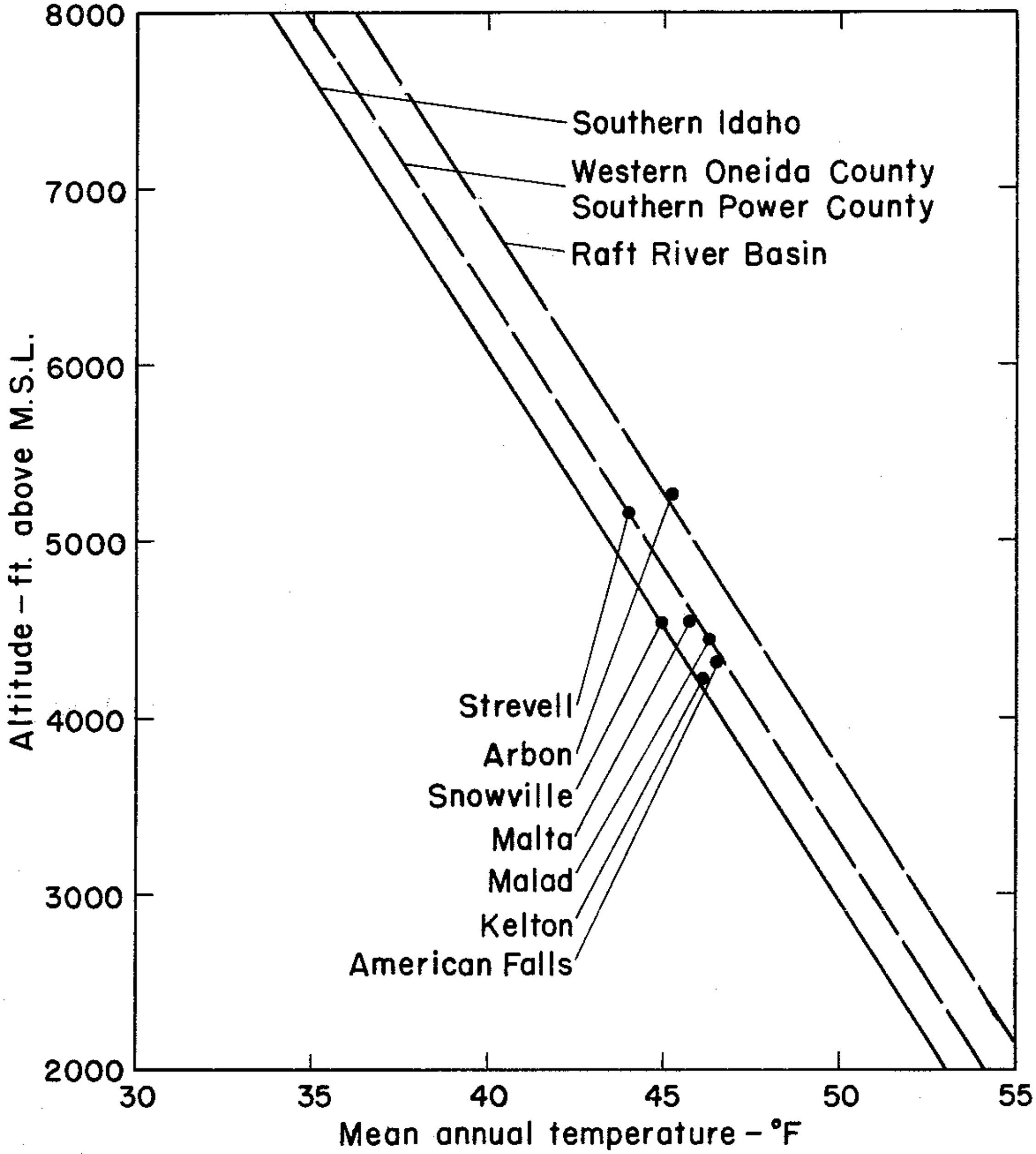

FIGURE 7. Relationship between temperature and altitude (modified from Nace and others, 1961).

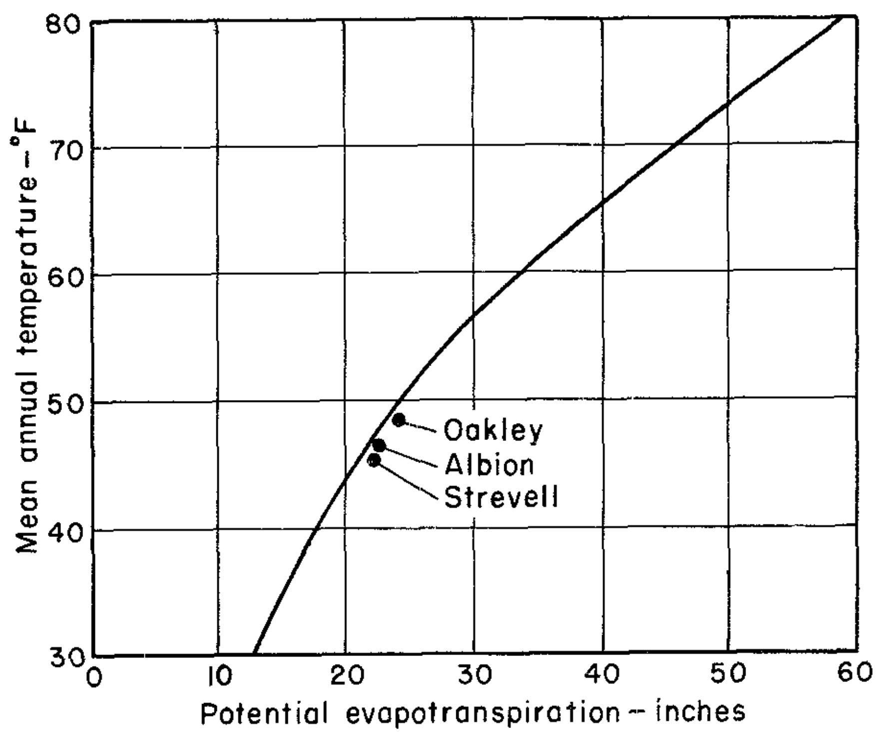

FIGURE 8. Relationship between mean annual temperature and potential evapotranspiration in North America (after Nace and others, 1961).

Water yield represents the runoff from the indicated altitude, but all of this water may not actually leave the basin if the water is subject to evapotranspiration by irrigated crops and phreatophytes or evaporation from reservoir surfaces.

Using the runoff value derived for each altitude zone (column 7, table 5), an estimate of runoff was made for each subarea (table 6). The area within each altitude zone was determined for each subarea by use of a planimeter. Areas on the topographic map were measured, then the water yield value was determined for the mid-point of each zone. For example, the average annual water yield of 2.3 inches corresponding to an elevation of 6,000 feet was applied to the area between the 5,500 and 6,500 foot contours. The total water yield for each subarea was determined by summing the water yield from each altitude zone.

The estimates of average annual water yield vary from 1.3 inches for Pocatello Valley subarea to 1.8 inches for the Arbon subarea. For comparison, an average annual water yield of 2.2 inches was estimated by the USGS for the combined Black Pine and Curlew subareas using another empirical method (Bolke and Price, 1969, p. 13). Estimates of 2.2 and 1.4 inches have been calculated by the USGS for the nearby Raft River Basin which has topography similar to the present study area (Nace and others, 1961, p. 31; and Walker and others, 1970, p. 46). An average annual water yield of 4 inches for the Malad River basin has

Table 6

Summary of Calculation of Water Yield from each Subarea

in the Western Oneida County Study Area

Subarea	Altitude Zone	Total Area of Subarea	Percent of Subarea in Altitude Zone	Water Yield Rate		Water Yield
-	Ft. above MSL	Acres	-	Inches	Feet	Ac-ft
Black Pine	Above 7,500	150,000	3	11.9	0.99	4,450
	6,500 to 7,500	150,000	10	5.8	0.48	7,250
	5,500 to 6,500	150,000	28	2.3	0.19	8,050
	4,750 to 4,500	150,000	41	0.57	0.047	2,900
	Below 4,750	150,000	18	0.31	0.026	700
				Total (rounded)		23,000
Curlew	Above 7,500	250,000	1.2	11.9	0.99	3,000
	6,500 to 7,500	250,000	9.5	5.8	0.48	11,500
	5,500 to 6,500	250,000	32.2	2.3	0.19	15,400
	4,750 to 5,500	250,000	94.4	0.57	0.047	5,200
	Below 4,750	250,000	12.7	0.31	0.026	800
				Total (rounded)		36,000
Pocatello	Above 6,500	55,000	6.8	5.8	0.48	1,800
	5,500 to 6,500	55,000	29	2.3	0.19	3,000
	Below 5,500	55,000	64	0.57	0.047	1,600
				Total (rounded)		6,000
Arbon	Above 7,500	145,000	1.1	11.9	0.99	1,600
	6,500 to 7,500	145,000	10.3	5.8	0.48	7,200
	5,500 to 6,500	145,000	34.0	2.3	0.19	9,500
	Below 5,500	145,000	54.6	0.57	0.047	3,800
				Total (rounded)		22,000

been estimated by the USGS using a method similar to that used in this report (Pluhowski, 1970). The Malad drainage has a greater percentage of area above 6,000 feet than does any of the areas in this study and thus the average annual water yield is higher in that basin than in the report area. The result obtained in this study agrees well with those determined in other investigations but additional climatic data are needed to increase confidence in the result.

The U. S. Army Corps of Engineers estimated an average water yield for the Arbon subarea of 2.4 inches (U. S. Army Corps of Engineers, 1948). This estimate was based upon a higher average precipitation (19 inches) than that indicated by more recent precipitation records.

SURFACE WATER

Three of the four subareas studied have significant surface-water resources. Bannock Creek in the Arbon subarea and Deep Creek in the Curlew subarea are important resources which affect the economy of the area. The pond which forms during flood periods in the Pocatello subarea can also be considered a significant resource in that it now adversely affects farming operations, but also represents a potential source of irrigation water. Surface water in the Black Pine subarea is limited to only a few small springs and ephemeral streams which can not be considered as important resources.

Curlew Subarea – The Curlew subarea is divided into two drainage basins above the town of Holbrook. The western basin is drained by Rock Creek (sometimes called Twin Springs Creek) which has a small perennial flow for several miles below Twin Springs (Section 30, Township 13 South, Range 32 East, B.M.). However, the stream channel is normally dry for several miles above its intersection with Deep Creek near Holbrook. A crest-gage station has been maintained by the USGS on Rock Creek in Section 9, Township 14 South, Range 32 East since 1962. The maximum flood flow observed at this station was 1,390 cfs in February 1962. Typical summer flow is estimated at approximately one cfs at this station.

The eastern arm of the Curlew subarea is drained by Deep Creek (sometimes called Bull Canyon Creek). Deep Creek is typically dry for several miles above and below Holbrook. Flow data for Deep Creek above Holbrook is limited to an estimate of 1,220 cfs for the peak discharge of the February 1962 flood. Holbrook Springs, in sections 12 and 13, Township 15 South, Range 32 East, provides a perennial flow of 25 to 35 cfs to the creek. The flow of the springs is reported to be relatively constant throughout the year, and a series of measurements made by the USGS during 1931 and 1932 seem to indicate that this is true (table 7).

The single measurement in 1970 indicates that the discharge of the springs is not greatly different from that measured in 1932.

Table 7

Miscellaneous Streamflow Measurements of Deep Creek

Date	Discharge (cfs)
November 19, 1931	31.8
April 14, 1932	30.4
May 23, 1932	26.6
July 4, 1932	27.5
October 15, 1932	28.0
August 7, 1970	26.0 (approx.) Baker, USGS, written communication (1970), flow above springs not included.

The flow of Deep Creek is used for irrigation of land in Idaho and Utah. A court decree in 1896 apportioned irrigation season flows totaling 31.46 cfs to 16 irrigators using water from Deep Creek. A later decree (1914) declared the natural flow of Deep Creek (30.26 cfs) to be the property of Curlew Irrigation and Reservoir Company during the irrigation season of April 20 to September 20, but allowed the Pratt Irrigation Company (now the Delmore Canal Company) to provide this flow from storage in Curlew Reservoir. This permitted the Pratt Irrigation Company to divert the flow of Holbrook Springs above the reservoir for irrigation use on Carey Act lands in Idaho.

The average annual volume of surface flow from the Curlew subarea to Utah is estimated to be 12,000 ac-ft/yr. This estimate is based upon the flows established by the 1914 decree and miscellaneous measurements of Deep Creek between Stone, Idaho and Snowville, Utah. The estimate of surface outflow does not include surface runoff from the area upstream from Holbrook Springs because data are not available. The average of five readings, taken on a four-foot Parshall flume located about 1 mile south of the Utah-Idaho state line, during the 1970 irrigation season was 8.2 cfs. The 1914 decree requires a flow of 8.7 cfs to be maintained in Deep Creek from April 20 to September 10 at the flume. The decree also calls for flows of 14.9 cfs and 6.2 cfs, respectively, in the east and west canals of the Curlew Irrigation Company. Interviews with local water users indicated that about one-half of the flow in these canals is used in Utah. The combined flow that leaves Idaho in Deep Creek and the irrigation canals during the irrigation season is approximately 19 cfs or a volume of 6,000 ac-ft for the 153-day period.

Only five measurements have been recorded for the flow in Deep Creek during the non-irrigation season. These measurements were all made during the early fall months and averaged about 7 cfs. Flow maintained in the east and west canals for stockwatering were estimated at 1 cfs during early fall. The shortage of data on flows during winter and spring makes another method of estimating the runoff desirable. For this report the non-irrigation season runoff is estimated at approximately 6,000 ac-ft/yr based upon the estimated volume of flow from Holbrook Springs less the storage of Curlew Valley Reservoir (6,000 ac-ft active storage capacity). Factors that tend to make this method inexact are: (1) evaporation from Curlew Valley Reservoir and water consumption by phreatophytes, (2) rainfall on Curlew Valley Reservoir and runoff from adjacent land, (3) net water loss to or gain from the ground-water system below Holbrook Springs, and (4) surface runoff entering Deep Creek above Holbrook Springs. Most of these factors are difficult to evaluate, but because the effects are often compensating the error caused by neglecting them is not considered significant.

Pocatello Valley Subarea – The pond that forms in the valley bottom during the spring months of wet years and following intense summer thunderstorms is locally a significant water resource. At present, the pond is significant because farming operations on land affected by the pond must be delayed until the water level recedes. However, preliminary data collected by the U. S. Soil Conservation Service (SCS) on the volume and frequency of the forming of the pond indicates that it represents a potential source of water for early season irrigation (Closner, SCS, written communication, 1971). The following data on the size and volume of the pond has been collected by the SCS:

Table 8

Volume and Area Covered by the Flood Pond in the Pocatello Valley Subarea

Year	Area Flooded (acres)	Volume (ac-ft)
1962	3,630	12,160
1965	880	495
1966	1,630	1,760
Average	1,300	950

The average volume of the pond was based upon a topographic survey of the area that local landowners indicated normally is flooded. During an average year, the pond is dissipated by late May. The 1962 flood event was ranked as the largest of record by local landowners who have lived in the area for as long as 60 years.

Arbon Subarea – The following measurements are available for Bannock Creek from a gaging station operated by the USGS:

Table 9

Annual Runoff for Bannock Creek - Arbon Subarea

Water Year	Annual Runoff (ac-ft)
1956	15,410
1957	16,910
1958	15,630
Average	15,983

These measurements are for Bannock Creek at the northern boundary of the present study area just upstream from Rattlesnake Creek. Three miscellaneous measurements made with a flow meter at the same location during the summer of 1970 agree very well with the flows measured previously by the USGS (fig. 9) This indicates that upstream conditions have not significantly changed, and that the flows measured during the 1956-58 period are considered good estimates of the flow to be expected under present conditions. Precipitation during the years 1956 and 1958 was below average at American Falls and Malad; while precipitation during 1957 was about average at these stations. Thus, the outflow during 1957 is probably indicative of the average surface runoff to be expected from the Arbon subarea.

Most of the flow in Bannock Creek occurs during the non-irrigation season and is unavailable for irrigation diversion and use. Approximately 27 percent of the surface outflow occurs during the irrigation season. This estimate is based upon an irrigation season of April 15 to September 15 and upon the average monthly discharge measured by the USGS at the site near Rattlesnake Creek during the 1956-58 period. Thus, the surface-water resource of the Arbon subarea is not being fully utilized at this time.

GROUND WATER

Ground-Water Development -- Ground-water development in the area of investigation has been primarily for domestic and stock use. Approximately 400 wells have been drilled; of which 225 are for stock and domestic purposes, 56 are for irrigation, 2 are for oil exploration and at least 115, which were originally drilled for stock or domestic, have been abandoned.

Fifty-two wells have been drilled in the Pocatello Valley subarea (fig. 10). Only 21 of these are presently in use, all being for domestic or stock purposes. No irrigation wells have been drilled in this subarea. The wells in the valley range in depth from 198 to 426 feet with most between 200-300 feet deep.

The Black Pine subarea contains approximately 20 wells (fig. 11). Eight are for domestic or stock use, two for irrigation, one for oil exploration and nine have been

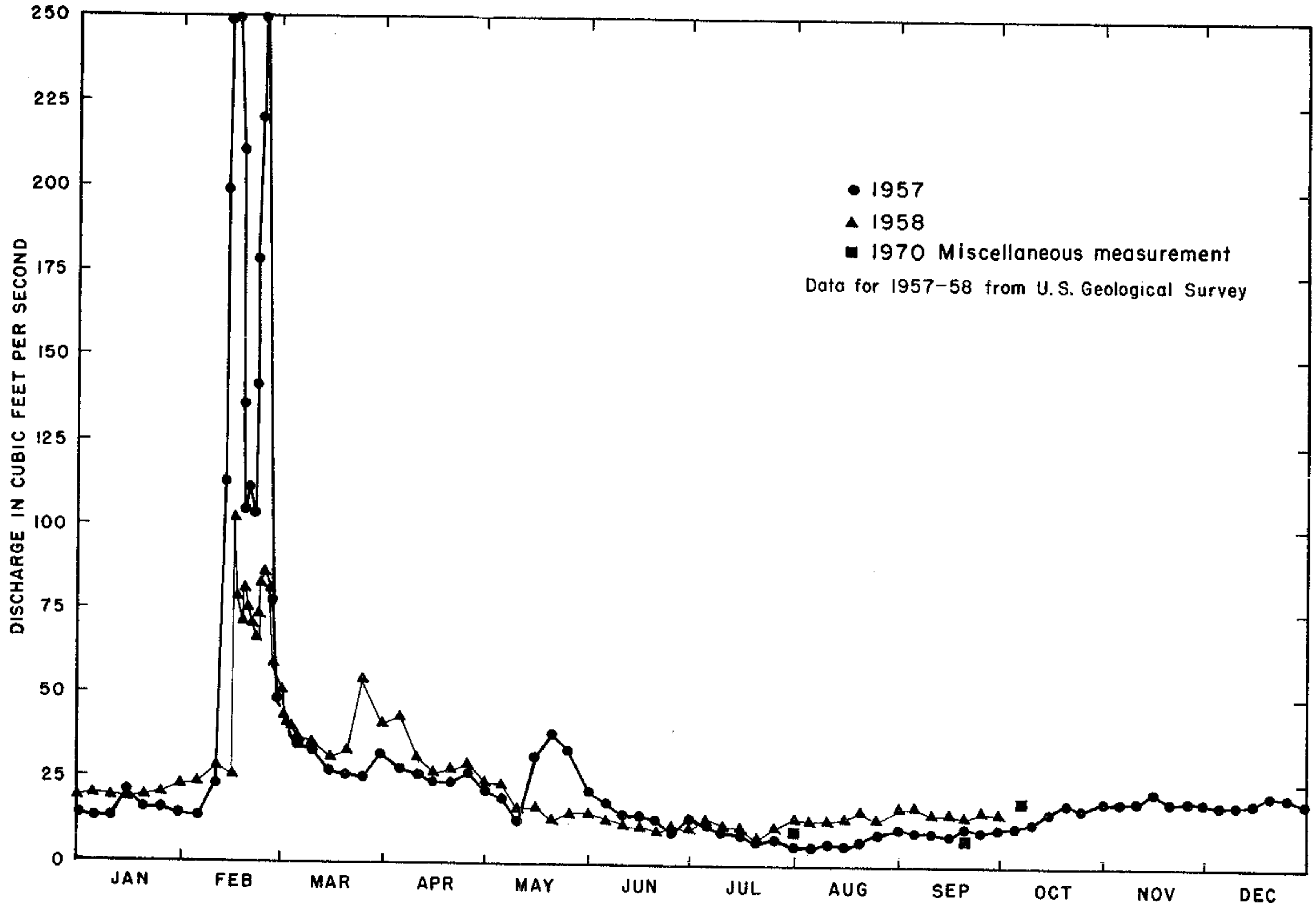

FIGURE 9. Flow of Bannock Creek near Pauline.

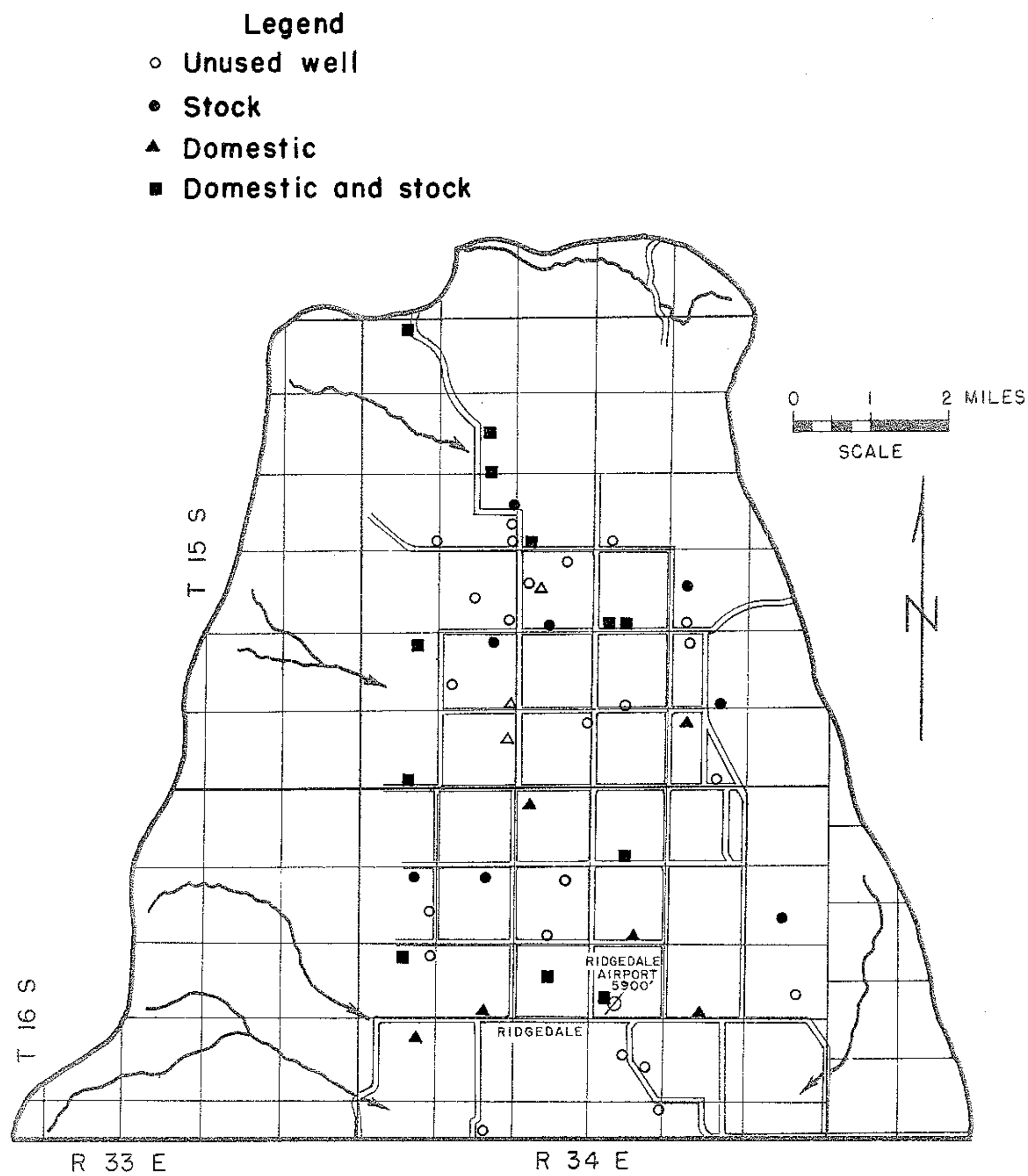

FIGURE 10. Location and use of wells in the Pocatello Valley Subarea.

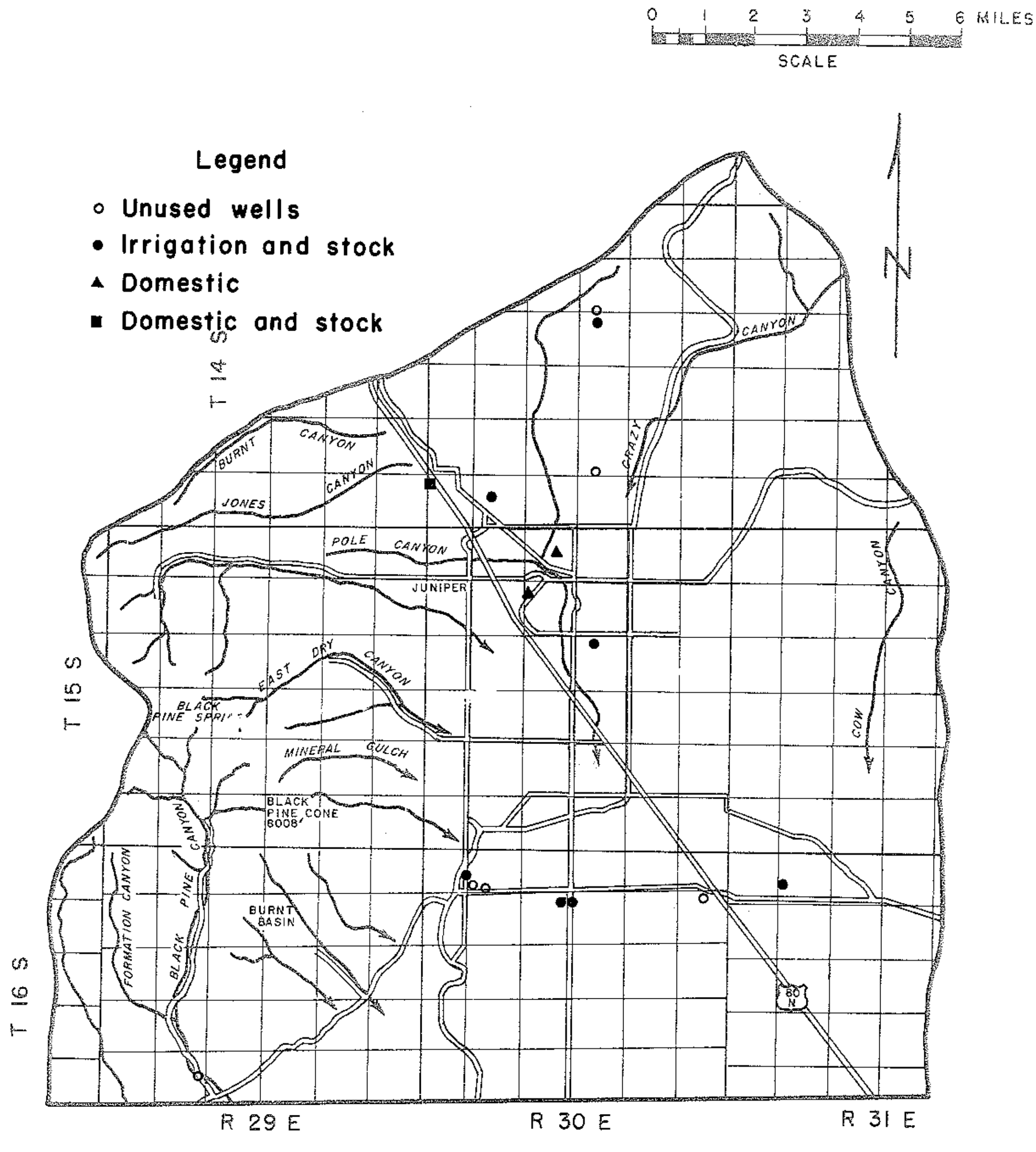

FIGURE 11. Location and use of wells in the Black Pine subarea.

abandoned. The water wells range in depth from 175 to 550 feet. The oil well is 12,844 feet deep. A large number of irrigation wells have been drilled just south of the Utah-Idaho state line. Most of these wells derive water from basalt aquifers, not generally encountered in wells in the Idaho portion of the valley.

Approximately 105 wells have been drilled in the Arbon subarea (fig. 12). Sixty-two of these are for domestic and stock use, nine are for irrigation, two were drilled for oil or gas exploration and 32 have been abandoned. The water wells in the valley range from 60 to 203 feet deep with most being about 100-150 feet deep. The gas exploration well was drilled to a depth of approximately 3,670 feet.

The greatest irrigation well development in the study area occurred in the Curlew subarea. Approximately 230 wells have been drilled, 45 of which are irrigation wells. Domestic and stock wells number at least 185, of which 52 have been abandoned. The irrigation wells are concentrated on the southern half of the valley floor and range from 15 to 400 feet deep (fig. 13). The domestic and stock wells are widely scattered and were drilled to similar depths.

Ground-water development within the study area began in the early 1900's. However, most of the irrigation well development has occurred since 1953.

Depth-to-Water — The observed water levels in wells range from flowing to 540 feet below land surface. Some of the factors causing this wide variation are: depth of the well, penetration of the aquifer material, topography and lithology of the aquifer penetrated.

The water levels in wells in the Curlew subarea range from flowing to 300 feet below land surface (fig. 14). Wells on the valley floor generally have water levels less than 50 feet below land surface. Wells developed on the side slope of the valley or in the foothills west of Holbrook have depth-to-water as great as 300 feet. These wells generally derive ground water from the Paleozoic rocks while the wells on the valley floor derive water from the valley fill materials.

Wells in the Black Pine subarea have depth-to-water ranging from 24 to 540 feet below land surface (fig. 15). Most of the water levels, however, are less than 150 feet. This wide range is believed to be the result either of recharge entering the ground-water system at different levels or that there exists two or more poorly connected aquifers in the valley. These aquifers probably become better connected to the south as the rock materials become more uniform. Evidence supporting this is the uniform depth-to-water of approximately 175 feet in wells just south of the Utah-Idaho state line which indicates a single ground-water system.

Wells in the Arbon subarea have depth-to-water ranging from 3 to 140 feet below land surface (fig. 16). This narrower range is due to a more uniform depth of wells and aquifer

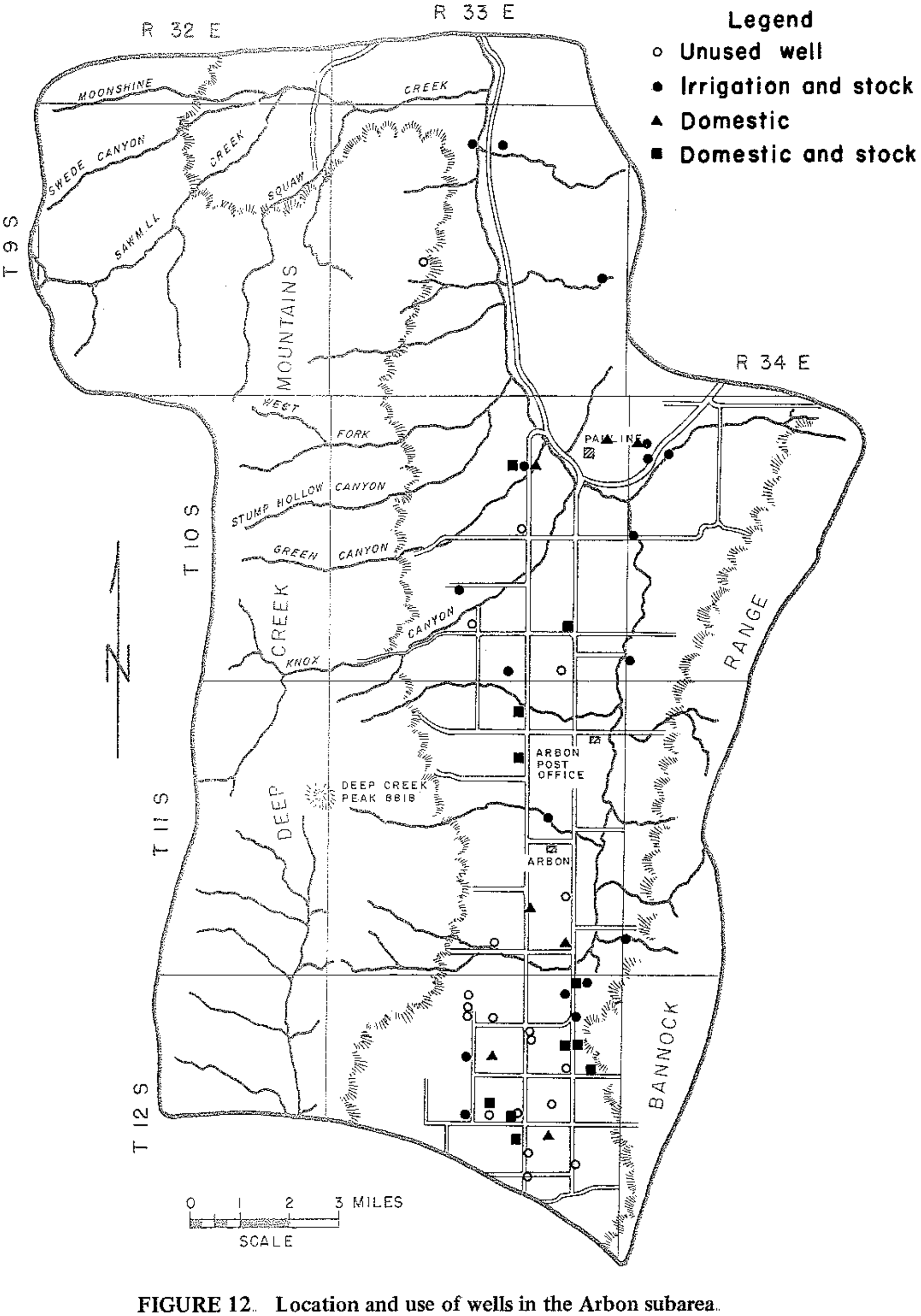

FIGURE 12. Location and use of wells in the Arbon subarea.

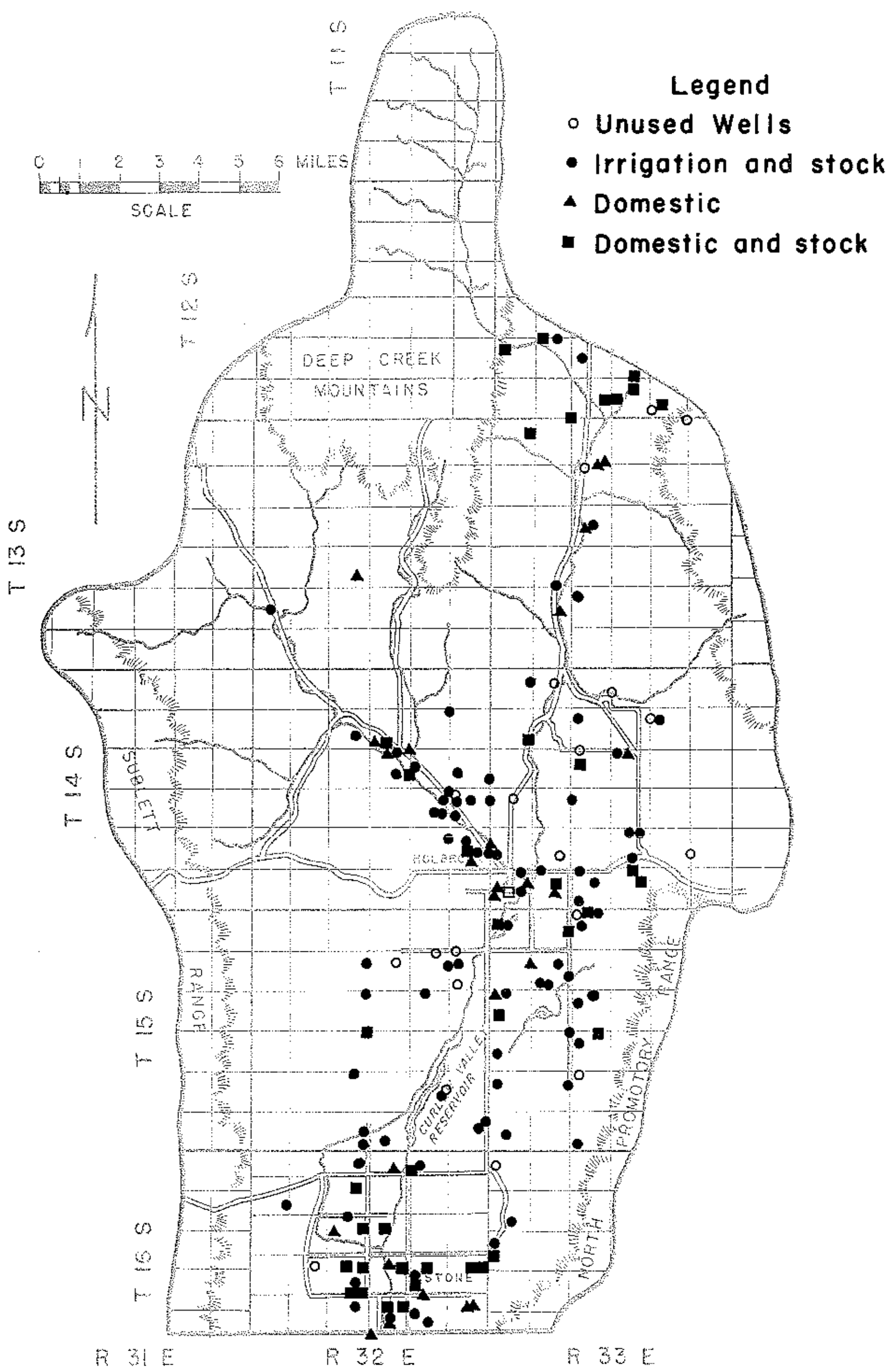

FIGURE 13. Location and use of wells in the Curlew subarea.

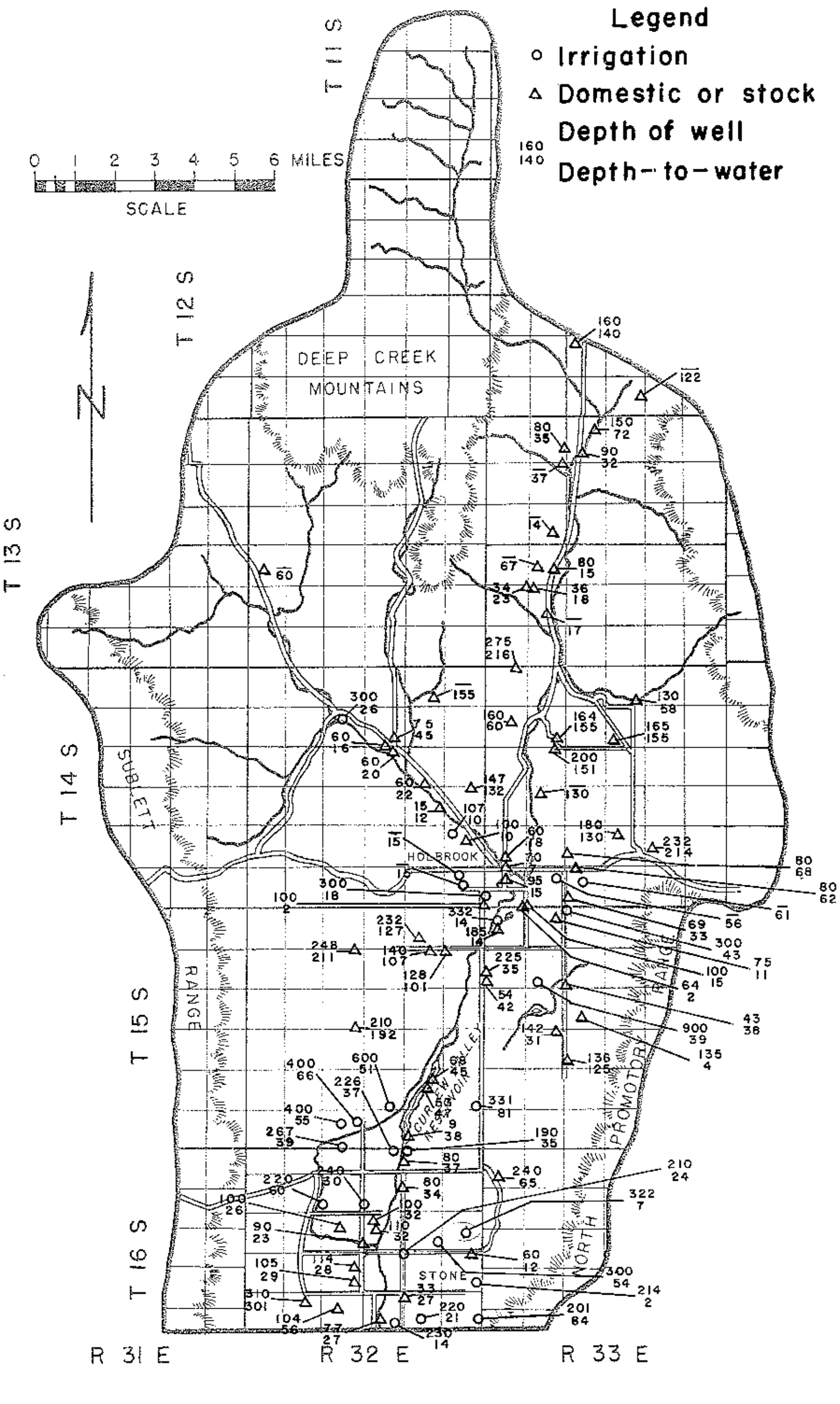

FIGURE 14 Location, depth and depth-to-water in wells in the Curlew subarea.

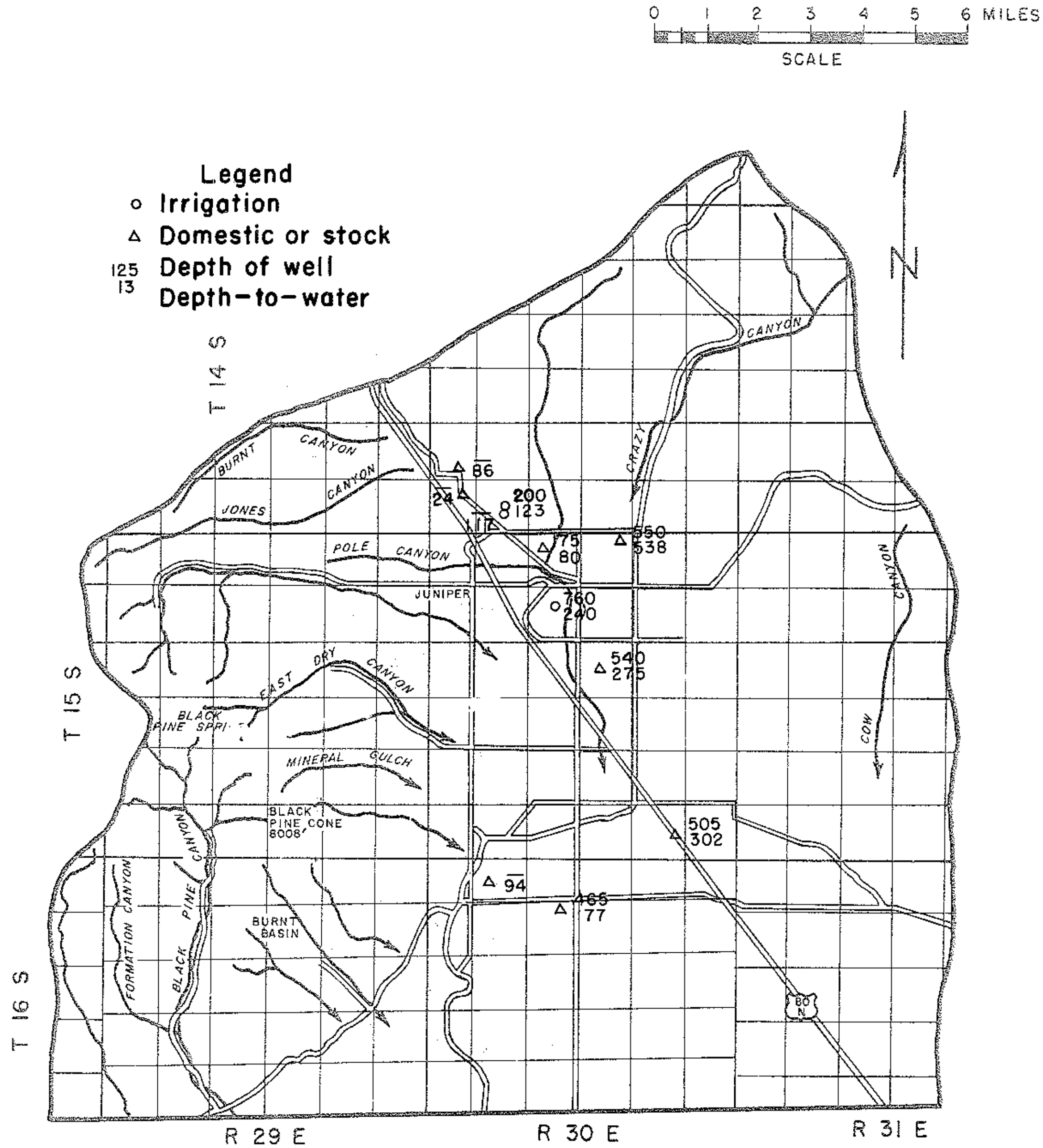

FIGURE 15. Location, depth and depth-to-water in wells in the Black Pine subarea.

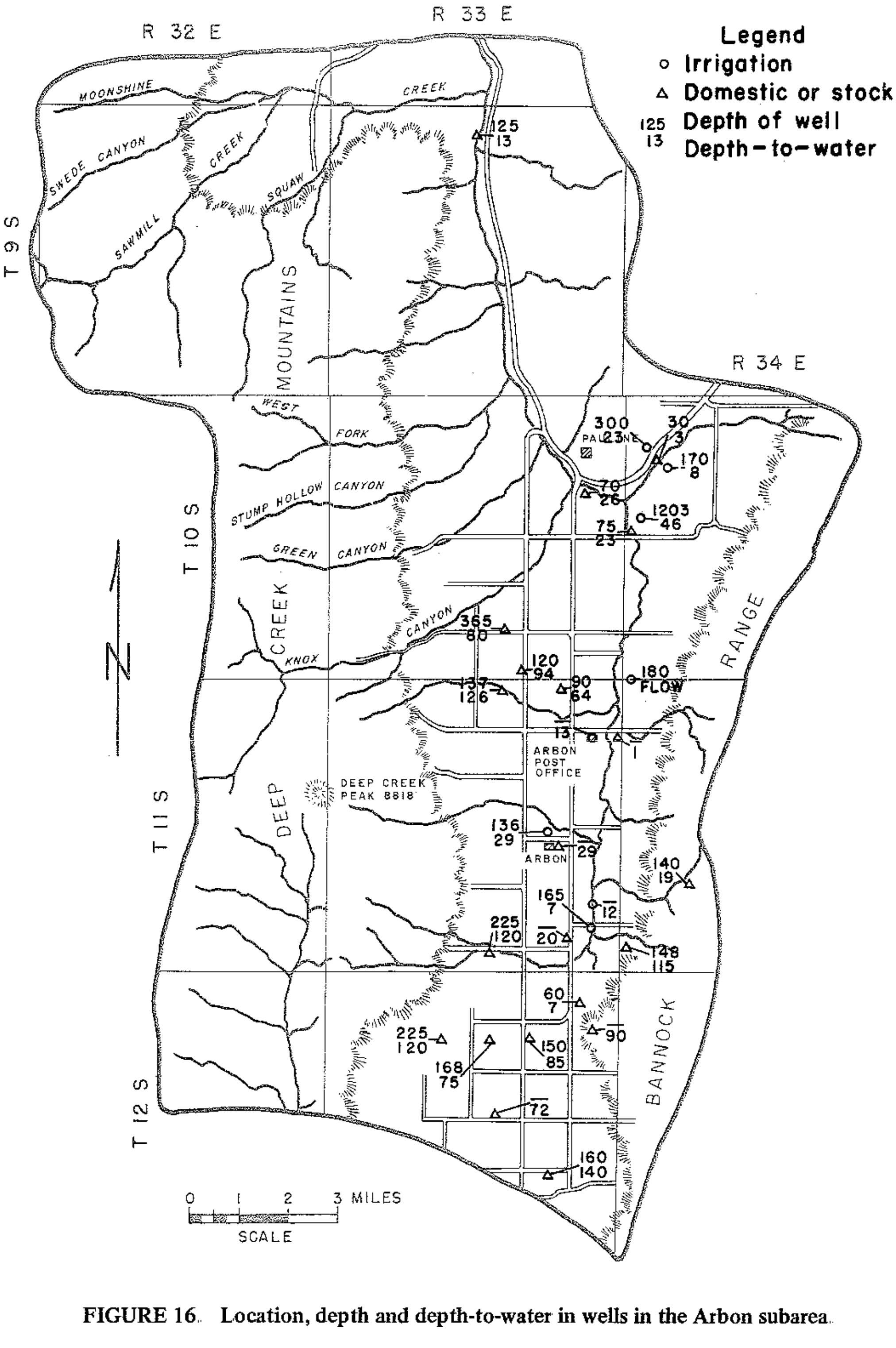

FIGURE 16. Location, depth and depth-to-water in wells in the Arbon subarea.

material encountered. Greater depth-to-water may be encountered in wells drilled along the side slopes of the valley and on topographic highs.

The water levels in wells in the Pocatello Valley subarea vary from 198 to 426 feet below land surface (fig. 17). This wide variation in believed to be the result of a large number of permeable lenses at different elevations in the valley fill. Because of the closed topographic nature of the basin, the geologic environment would result in alternating layers of fine and coarse grained materials to be deposited, all poorly connected. Ground-water recharge moving from the hills would travel through the coarser layers always trying to move downward to the regional water table. The water level in a well would be contingent upon the particular lense in which it is finished.

Yield-to-Wells -- The yield-to-wells varies widely over the study area. Because most of the wells are used for stock and domestic purposes few aquifer tests have been conducted. Data on the yield-to-wells were collected from the few pumping wells tests available, drillers' logs and water rights files. The data were then converted to specific capacity to help determine the hydrologic properties of the aquifers. The Sc of a well is defined as the yield of a well per unit of drawdown, usually expressed in gpm/ft. Since most wells are not pumped as heavily in production as in a test, the Sc values obtained for this study are considered to be minimal.

Wells in the Black Pine subarea have reported yields ranging from a few gpm in stock and domestic wells to approximately 80 gpm in irrigation wells. Specific capacities for this subarea range from 5 to 80 gpm/ft for the wells tested.

The Arbon subarea contains wells having yields up to approximately 450 gpm. Specific capacities for those wells with tests range from 24 to 56 gpm/ft. These high values indicate a good potential for irrigation wells in the central portion of the valley.

The greatest amount of data is available for the Curlew subarea, including aquifer tests for 21 wells. The yield-to-wells in this subarea range from a few gpm in the stock and domestic wells to 3,600 gpm in large irrigation wells. Specific capacities for the subarea range from approximately 1 to 100 gpm/ft. The higher values were obtained from wells penetrating the sand and gravel aquifer in the south-central portion of the valley.

One aquifer test was conducted during this investigation. A pumping well (16S 32E 27dab1) and five observation wells at distances ranging from 1,950 to 4,530 feet from the pumped well were selected. The well was pumped continuously for a period of 48 hours while measurements of drawdown were made in all wells. Recovery rates were measured for 27 hours after the well was turned off. Data obtained from the test were analyzed by several methods to determine storage and transmissibility coefficients. The Theis non-equilibrium well formula (Theis, 1935) was used to determine transmissibility (T) and the storage coefficient (S). T is defined as the number of gallons of water that will pass in one day

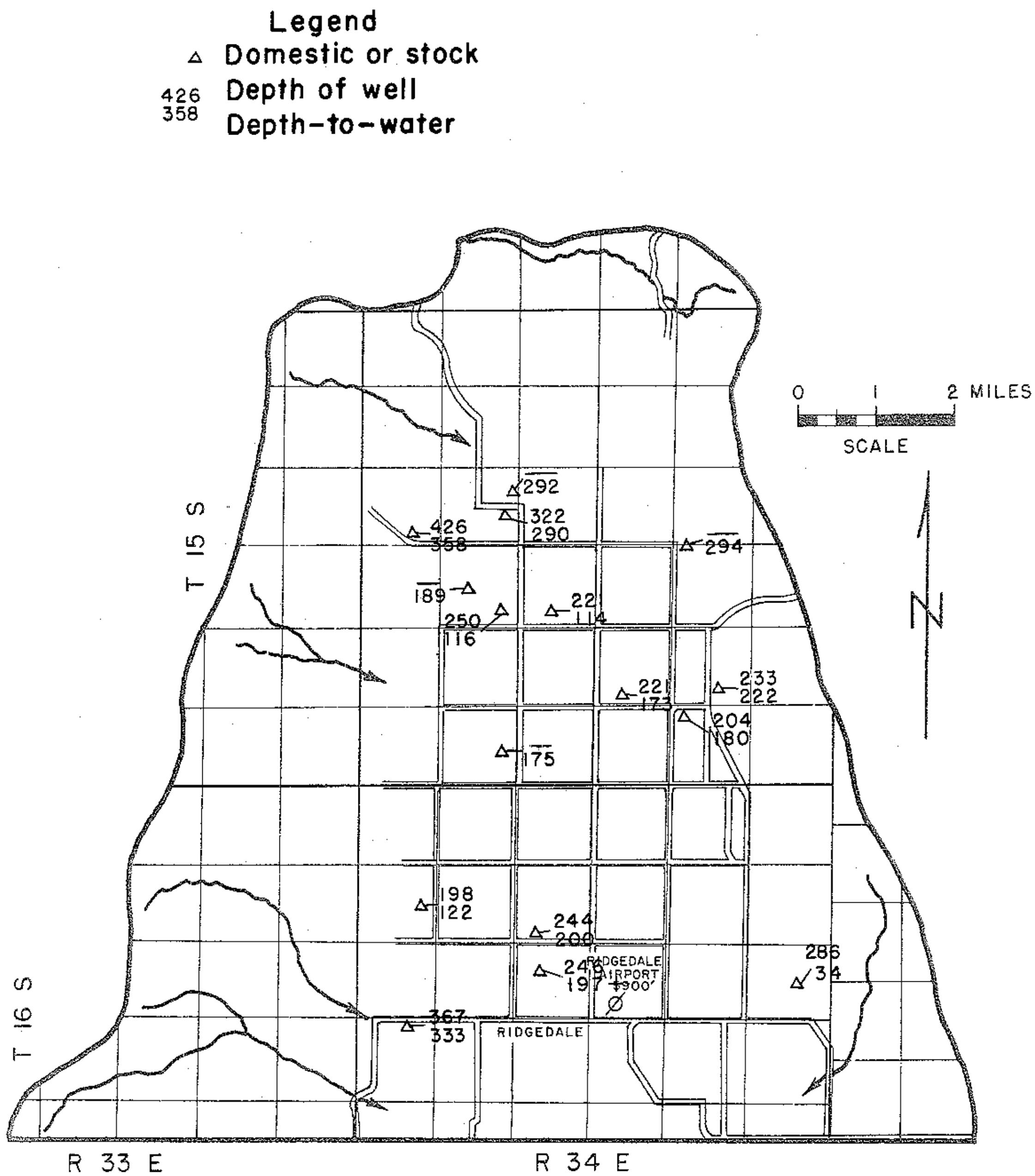

FIGURE 17. Location, depth and depth-to-water in the Pocatello Valley subarea.

through a vertical strip of the aquifer, 1 foot wide, having a height equal to the saturated thickness of the aquifer, under a hydraulic gradient of 100 percent and S is defined as the volume of water the aquifer releases or takes into storage per unit surface area, per unit change in the component of head normal to that surface. The type-curve method was used during the drawdown phase of the test. As a check upon the accuracy of these calculations, the recovery data were utilized in the formula: (Theis, 1935):

$$T = \frac{264\,Q}{\Delta s'}$$

Where:	T	=	the coefficient of transmissibility
	Q	=	pumping rate in gpm
	$\Delta s'$	=	the change in residual drawdown per logarithmic cycle of t/t'
Where:	t	=	time since the pump test started
	t'	=	time since the pump stopped

Upon calculation, the T ranged from 30,000 to 60,000 gpd/ft in the pumped well. This range is calculated from the recovery curve shown in figure 18. Transmissibility values ranged up to 4,260,000 gpd/ft in the observation wells. This extreme variation is believed to be the result of the following factors: (1) the aquifer is weakly artesian, (2) the aquifer materials are non-uniform, (3) boundary conditions occurred in the late stages of pumping, and (4) the well penetrated only a portion of the aquifer. Because of the wide variation in the transmissibility values determined for the pumped and observation wells the average transmissibility of the aquifer is believed to be approximately 150,000 to 250,000 gpd/ft. This is based on the best data collected during the pumping well test and Sc values for other wells penetrating the aquifer. The storage coefficient of the aquifer as determined, ranges from approximately 1.0×10^{-3} to 2.0×10^{-3}.

Water-Level Fluctuations – Water-level measurements have been made by other investigators since 1931. Some of the wells measured in 1931 and 1947 in the Curlew subarea were measured as a part of this study. These measurements indicate that water-level changes since 1931 have ranged from a 3-foot rise to a 10-foot decline in the portion of the subarea south of Holbrook. No long-term data were available for the upper portion of the subarea. Short-term water-level records (April to October, 1970) show water-level changes of +2.5 feet to -23 feet in the Curlew subarea (fig. 19). Declines noted are believed to be primarily the result of ground-water pumpage. Water levels are expected to recover during the winter months. Water-level measurements on several wells during November 1970 showed a rise of as much as 10 feet from the measurement of the previous month strengthening this conclusion.

Water-level changes in the Pocatello Valley subarea ranged from negligible change to -2 feet for the period April-October, 1970 (fig. 19). This small water-level change is believed

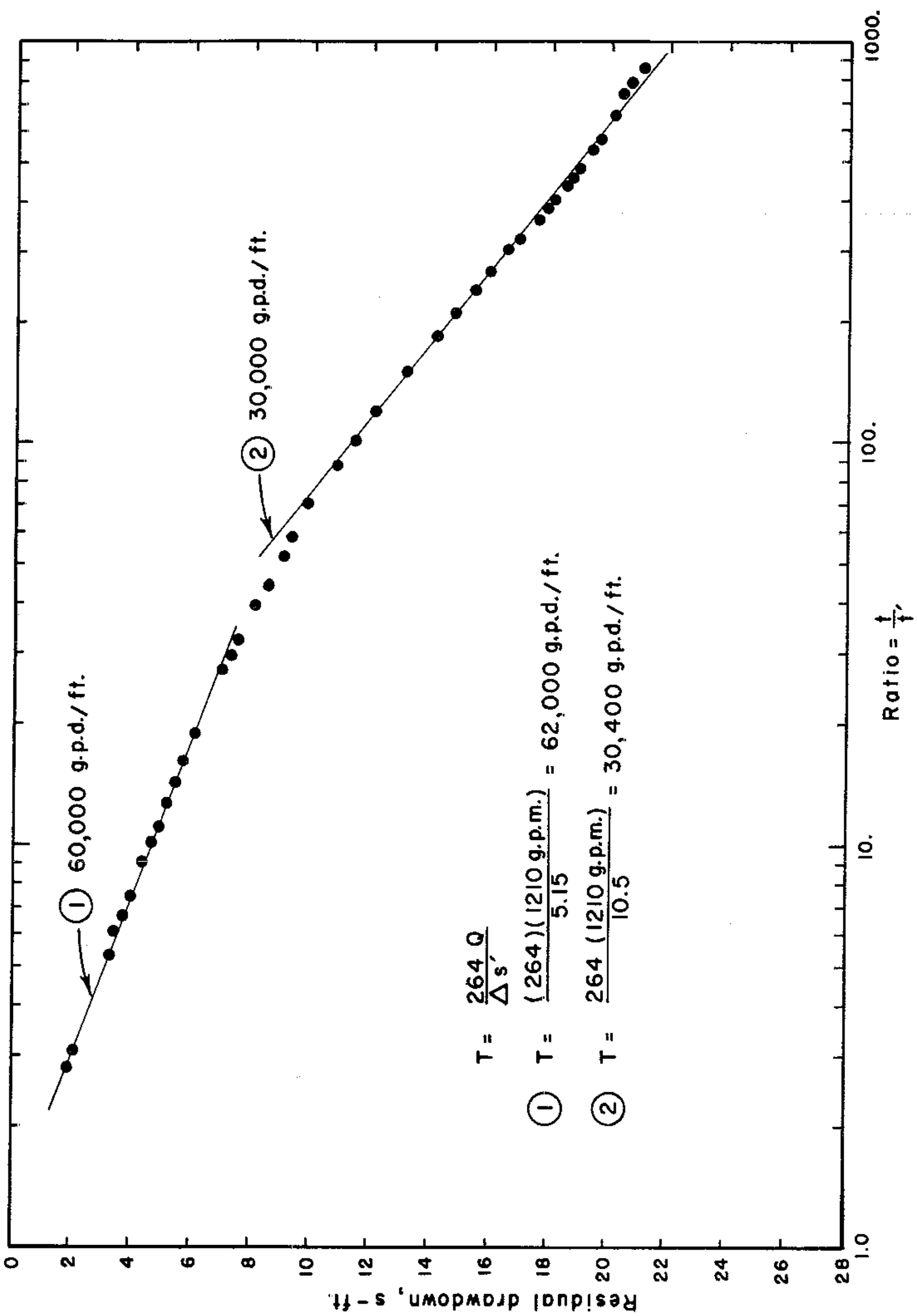

FIGURE 18. Residual drawdown curve of well 16S 32E 27dab1.

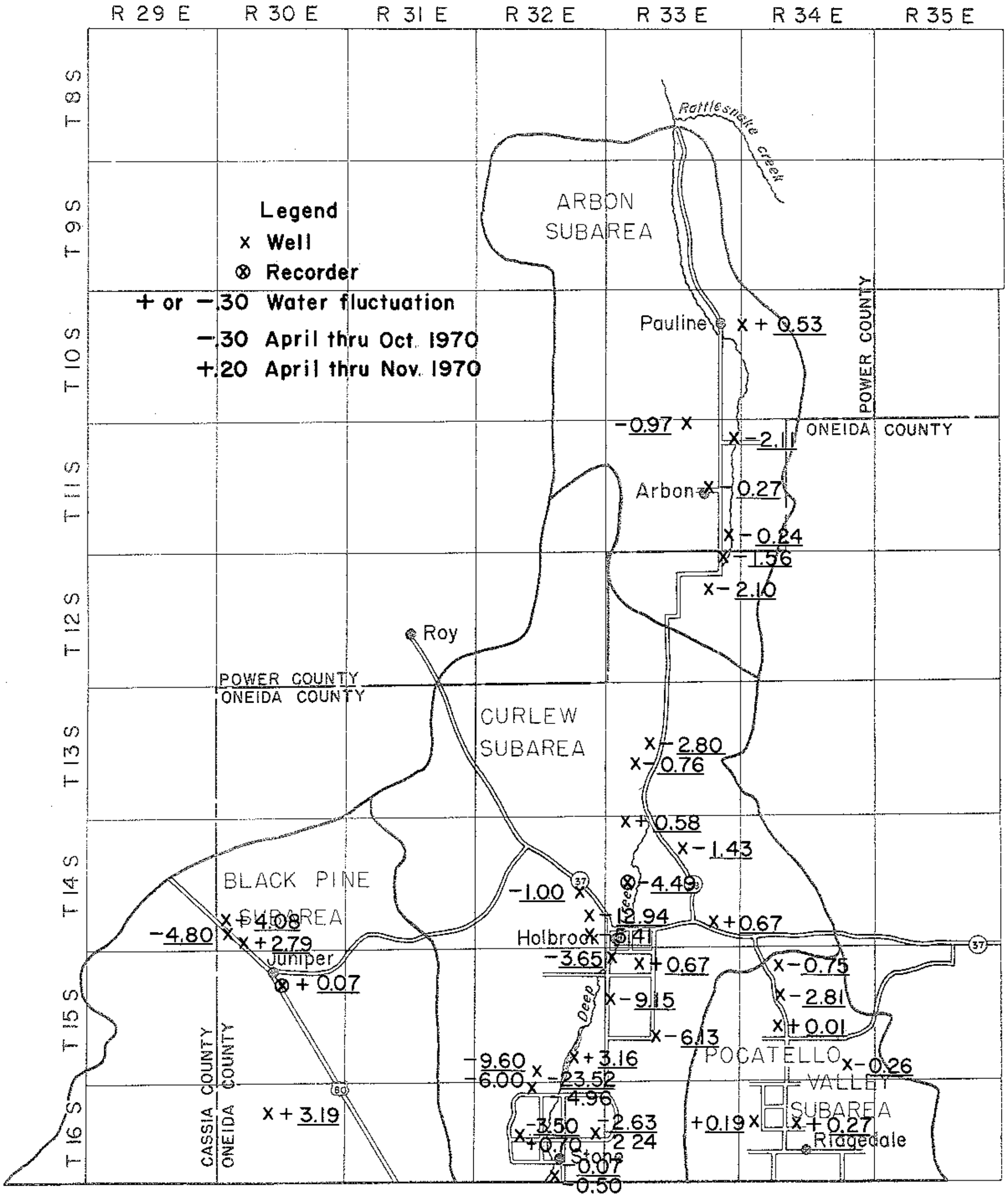

FIGURE 19. Water-level fluctuations in the western Oneida County study area.

due to: (1) the complete lack of ground-water pumpage for irrigation, and (2) the small amount of water recharging the general ground-water system which results in minimal seasonal fluctuation.

The Arbon subarea water levels underwent changes from 0 to -2 feet for the period April-October, 1970 (fig. 19). The declines shown in figure 20 in wells 11S 33E 1ddc1 and 11S 33E 25ca1 are the result of pumpage for irrigation and are not representative of the entire subarea.

Water levels in the Black Pine subarea rose with one exception, well 14S 30E 31ac1 which declined approximately 4 feet (fig. 19). This well is believed to tap a shallow aquifer which becomes depleted during the summer months when it is used for stock watering. The other wells in the subarea are mostly for domestic purposes, are pumped intermittently, and are generally over 100 feet deep. It is believed that the reason for the rise in water levels is due to the lack of heavy pumpage and a time lag of several months during which spring recharge slowly moves into the ground-water system, reaching a peak in August. One well, 15S 30E 8da1, which derives water from sediments deeper than any of the other wells in the valley, showed no significant change in water level for the period of record. This indicates both a lack of pumpage from the aquifer and a probable minimal recharge to the system.

Ground-Water Movement – The direction of ground-water movement was determined by converting the depth-to-water values obtained in the field to elevations above mean sea level. Elevations of the measuring points were established from previous studies, topographic maps and spirit leveling. Plotting the water surface elevation provides an indication of the gradient or slope of the water surface and its direction of movement. A contour map of water-level elevations was constructed for three of the four subareas (figs. 21, 22 and 23).

Ground-water movement in the Arbon subarea is generally from south to north. Contours of water-level elevation (fig. 21) indicate water enters the ground-water system along the mountain front, moves toward the center of the valley floor and then turns northward to flow out the lower end of the subarea. The gradient of the ground-water surface along the mountain front is very steep, approximately 150 ft/mile, and flattens to about 10 ft/mile in the center of the valley. The contours indicate the recharge to the subarea is from precipitation on the Deep Creek Mountains and Bannock Range. The approximate location of a ground-water divide between the Arbon and Curlew subareas is shown in figure 21. Water entering the aquifer north of this divide flows into the Arbon subarea, water entering south of it flows to the Curlew Valley subarea. This ground-water divide corresponds closely to the surface-water drainage divide.

Ground water in the Curlew subarea generally flows in a southerly direction (fig. 22). The majority of the recharge comes from precipitation on the Deep Creek, Sublett and North Promontory ranges with minor recharge from the reservoir. Recharge enters the permeable rocks and alluvium along the hill front and moves toward the center of the valley,

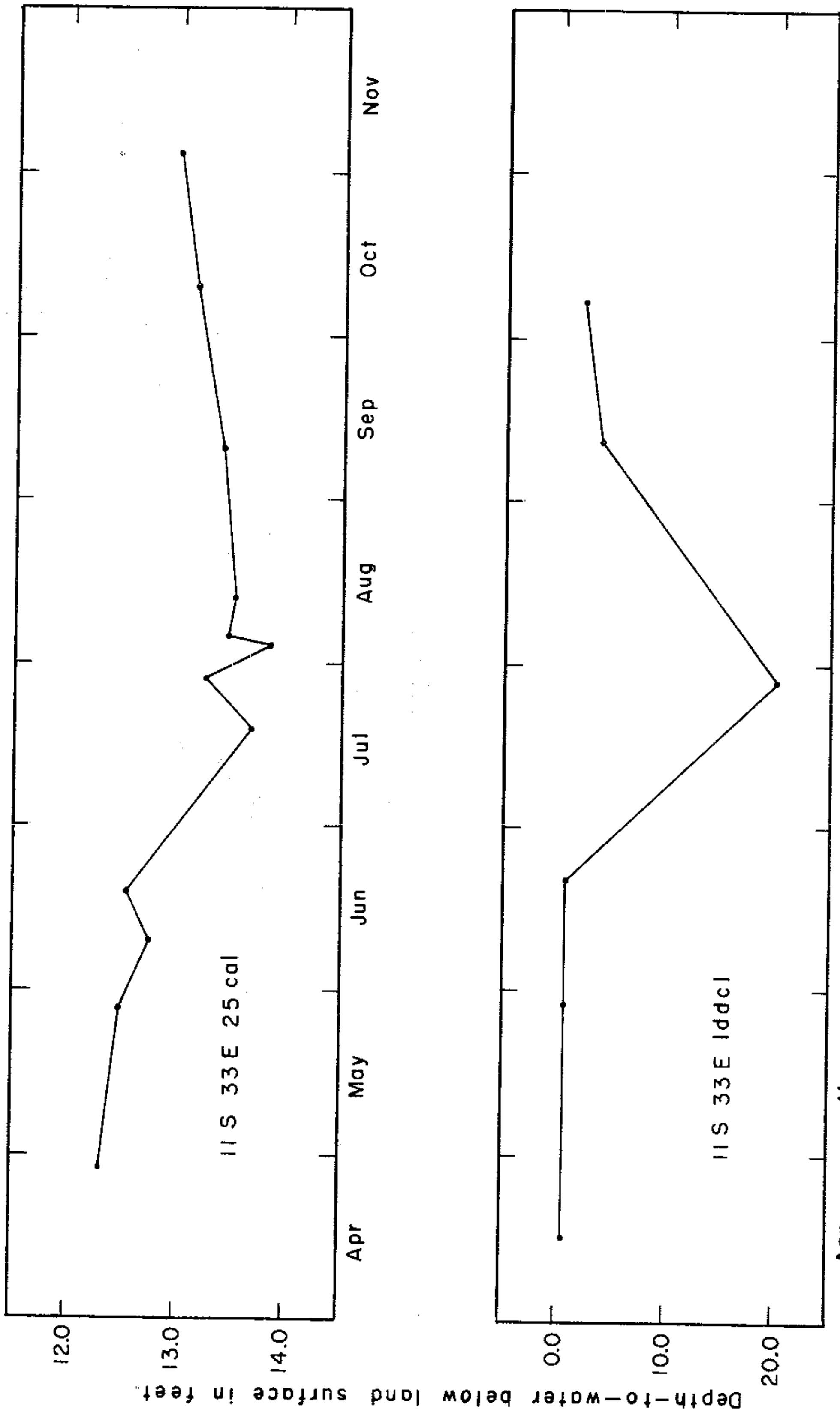

FIGURE 20. Hydrographs of wells 11S 33E 1ddc1 and 11S 33E 25ca1.

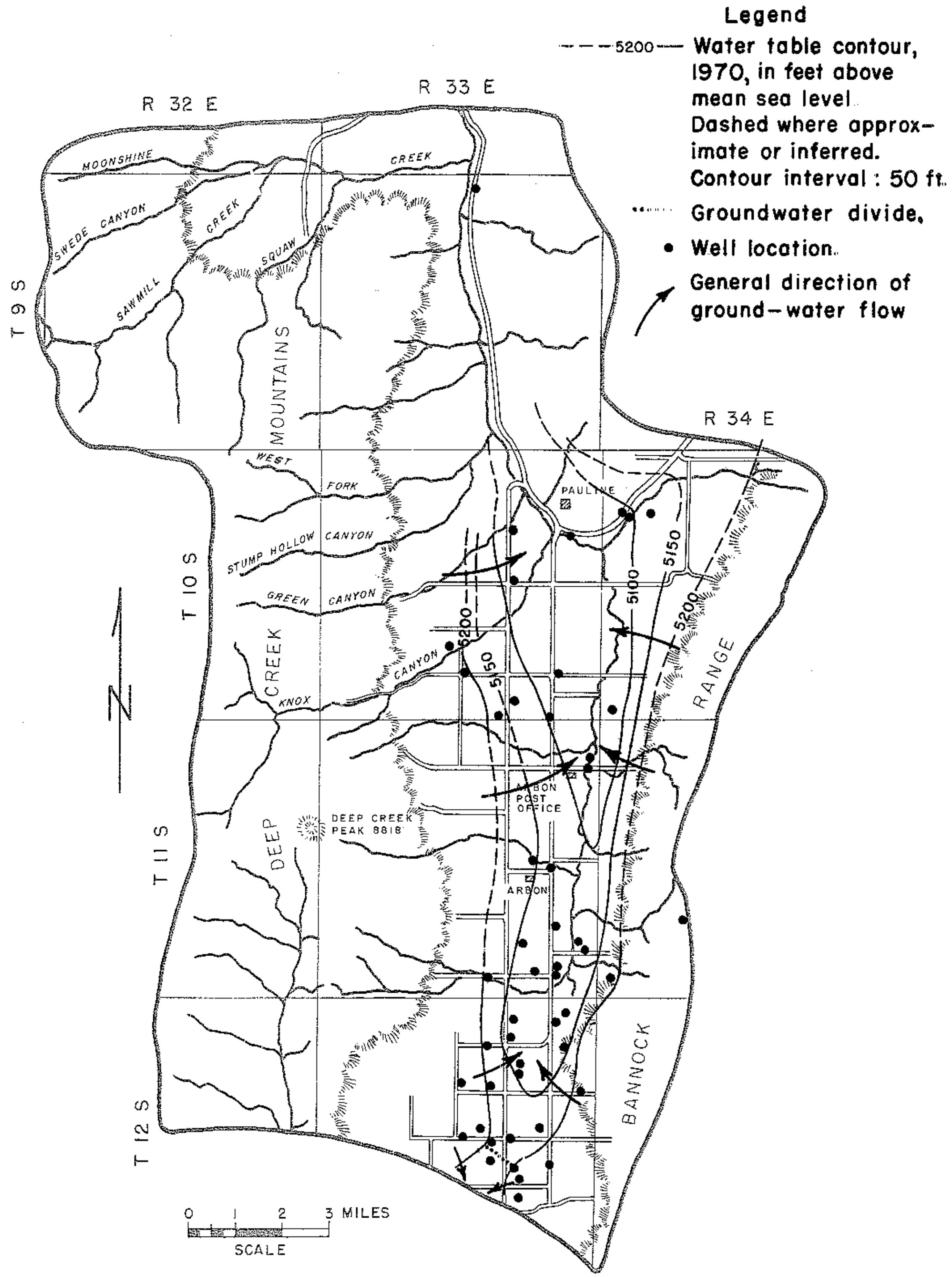

FIGURE 21 Contours of water-level elevation for the Arbon subarea.

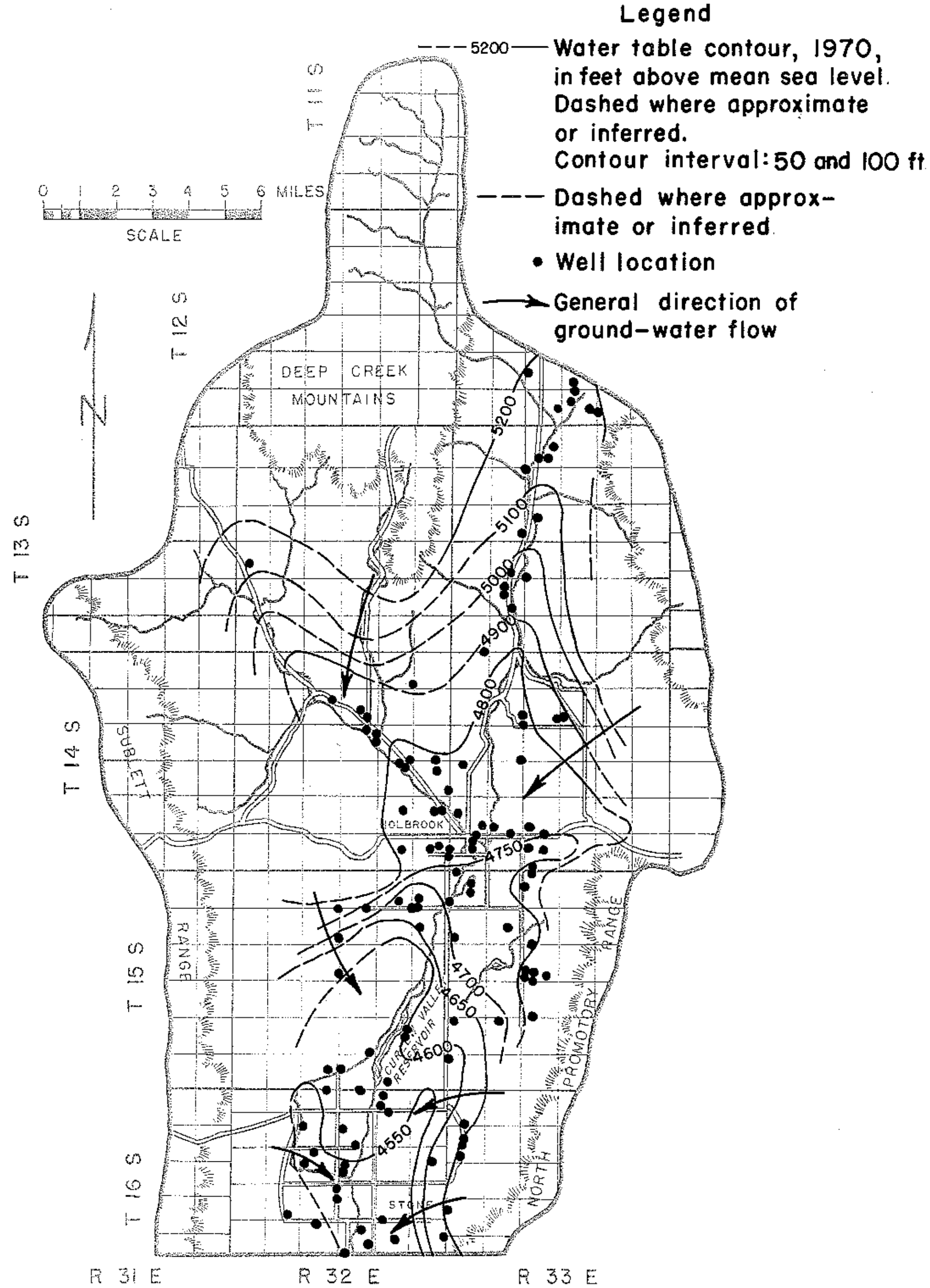

FIGURE 22. Contours of water-level elevation for the Curlew subarea.

eventually turning southward toward Utah. The gradient of the ground-water surface varies from approximately 100 ft/mile in the northern end of the valley to 8 ft/mile on the valley floor. There are local variations caused by changes in geologic features or local areas of recharge or discharge. The flat gradient shown near Holbrook in figure 22 is believed to be the result of a combination of the greater cross-sectional area of the aquifer for water to move through and an increase in permeability. The flat gradient near Curlew Valley Reservoir is believed to be the result of recharge to the ground-water system from the reservoir into the permeable upper gravels. The contours also show that recharge from the reservoir is occurring to the aquifer south of the reservoir.

Discharge from the aquifers in the subarea is by: (1) spring discharge, (2) pumpage, (3) underflow to Utah, (4) seepage to Deep Creek, and (5) consumptive use by plants. The greatest discharge from the ground-water system is from Holbrook Springs in sections 12 and 13, Township 15 South, Range 32 East. The springs appear to issue from semi-consolidated gravels, probably belonging to the Salt Lake Formation. This spring flow provides a great portion of the irrigation water for the lower part of the valley.

The contours of water-level elevation in the Black Pine subarea indicate that the ground water moves from the northwest to the south and southeast along the axis of the valley (fig. 23). The gradient of the ground-water surface is approximately 100 ft/mile in the upper valley and 50 ft/mile near the Idaho-Utah state line. These contours indicate that the recharge to the valley originates in the Sublett Range and Black Pine Mountains and that discharge from the system is to the south into Utah.

Water-level elevations in Pocatello Valley vary widely. Data from both a 1932 survey (Thompson & Faris, 1932) and this investigation indicate numerous aquifers are present. A contour map of the water surface elevation is not presented because the numerous water levels present in the subarea would make it meaningless. The wide variation of water levels is believed to be the result of a series of semi-perched zones, all poorly connected hydraulically. These perched systems lie upon a series of beds of fine-grained material deposited in a closed basin environment. Ground-water movement in the basin is therefor a function of the lithology of each aquifer system. Recharge to the aquifers is from precipitation on the Blue Spring Hills and the North Promontory Range. Discharge is believed to be to the south into Blue Spring Valley and possibly to the east into Malad Valley. Both assumptions are based on the lithology of the rocks in the valley and attitude; i.e., dip and strike, of the Paleozoic rocks in the Blue Springs Hills. These rocks generally dip eastward which would allow ground water to migrate downward along permeable bedding planes. Sufficient head difference, approximately 300 feet, is present between the ground-water systems in these valleys to allow such movement. Little data is available to the south but the information available indicates possible movement of ground water toward the Blue Spring Valley.

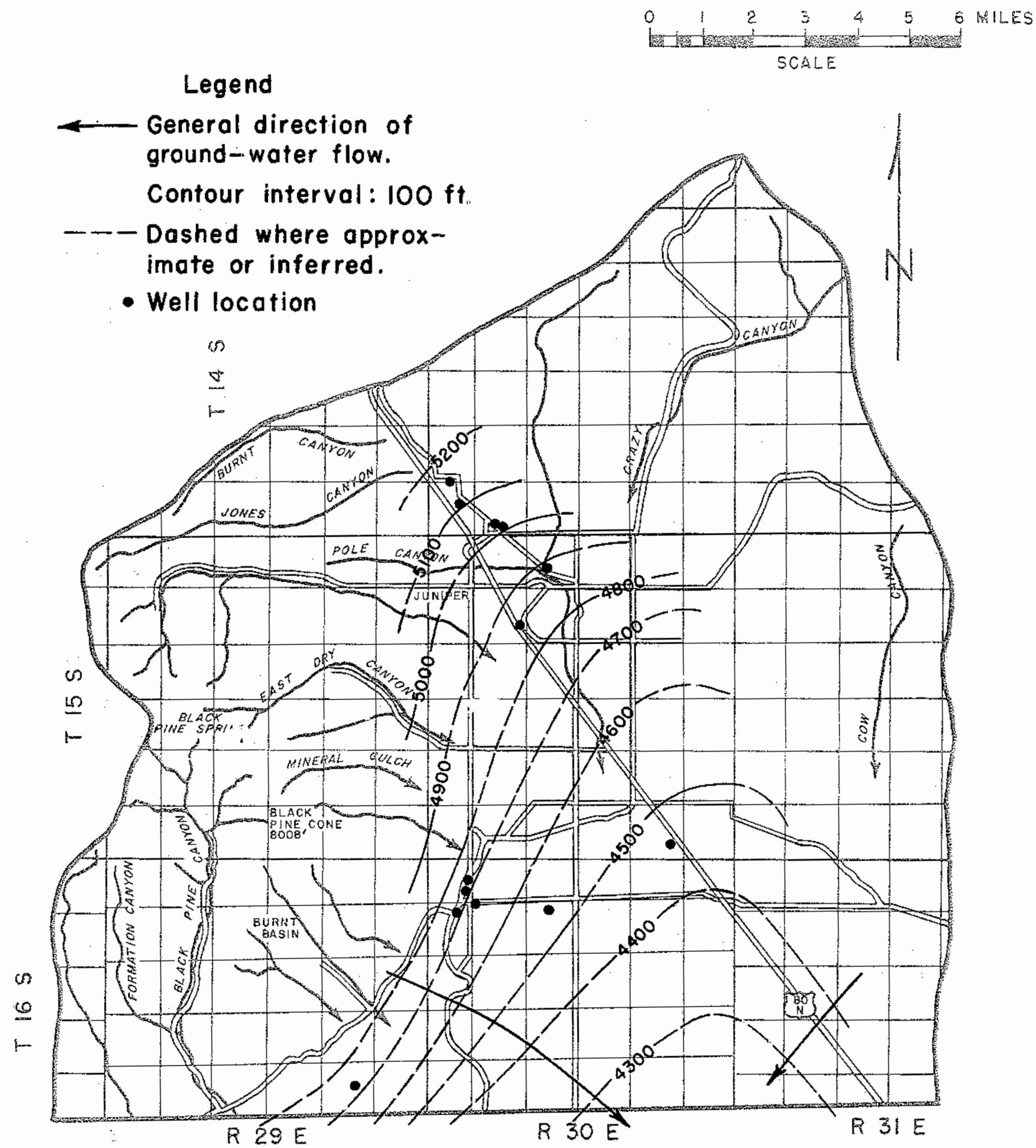

FIGURE 23. Contours of water-level elevation for the Black Pine subarea

WATER BUDGET

Water yield estimates indicate that approximately 90 percent of the precipitation is returned directly to the atmosphere by evaporation and evapotranspiration from native vegetation. The water consumptively used by dryland crops has been assumed to be approximately equal to the amount that would have been used by the native vegetation that was replaced. The water yield appears as either surface or subsurface runoff from the basin unless consumed by phreatophytes along streams, consumptively used by irrigated crops or evaporated from reservoir surfaces. The values presented in the water budget were calculated assuming that irrigation development using ground water did not exist (table 10). Thus, the values can be considered as representing runoff conditions with the present surface irrigation development but prior to extensive ground-water development.

Black Pine Subarea – The entire water yield of this basin can be assumed to leave as subsurface flow. Surface runoff is negligible during an average water year as only ephemeral streams exist. No irrigation usage is made of the surface water, and the great depth-to-water throughout most of the basin makes usage of ground water by phreatophytes negligible.

Curlew Subarea – The estimated water yield of Curlew Valley is 36,000 ac-ft/yr. Even before surface irrigation began, water use by the plants in the swampy areas along Deep Creek probably reduced the actual outflow by 3,000 ac-ft/yr. Evaporation from Curlew Valley Reservoir and water use by surface irrigation crops has further reduced the runoff. Prior to pumpage for ground-water irrigation, the runoff actually leaving the subarea is estimated to have been 12,000 ac-ft/yr surface-water outflow and 18,000 ac-ft/yr ground-water outflow.

Several methods of estimating the volume of ground water pumped are available. An estimate of 15,000 ac-ft/yr was calculated based upon Utah Power and Light Company's power consumption records and preliminary data relating volume pumped to power consumption. These factors were developed by Claud Baker of the Utah District office of the USGS for 19 electric-powered systems in the Curlew subarea during August of 1970. The 19 systems measured were distributed over the entire irrigated area. A discharge factor similar to that for a nearby rated well was assumed for wells for which factors were not measured. The estimate obtained by this method appears to be high as it indicates that nearly the entire estimated average annual recharge to the aquifers in the subarea is pumped.

As a check, a second estimate of pumpage was made based upon acreage irrigated and consumptive irrigation requirements of crops. The consumptive irrigation requirement for full irrigation averages about 21 inches for the crops typically grown in the area (Young and Ralston, 1971). Many of the wells in the Curlew subarea are used for supplemental irrigation - either to supplement surface supplies or to increase the production of predominately dryland. Thus, the actual ground-water use by crops may not actually average 21 inches over the estimated 5,000 acres upon which ground water is applied. Assuming the actual

Table 10

Water Budget for the Western Oneida County Study Area

(Rounded to nearest 1,000 ac-ft)

SUBAREA	WATER GAIN (ac-ft/yr)		WATER LOSS (ac-ft/yr)	
Black Pine	Precipitation	190,000	Evapotranspiration (Natural)	167,000
			Water Yield	23,000
			Evapotranspiration (Irrig. Crops)	
			Evapotranspiration (Phreato-phytes)	23,000
			Surface Outflow	
			Subsurface Outflow	
			Total	190,000
Curlew	Precipitation	320,000	Evapotranspiration (Natural)	284,000
			Water Yield	36,000
			Evapotranspiration (Sur. Irrig. Crops)	
			Evapotranspiration (Phreato-phytes)	36,000
			Evapotranspiration (Curlew Res.)	
			Surface Outflow	
			Subsurface Outflow	
			Total	320,000
Pocatello	Precipitation	70,000	Evapotranspiration (Natural)	64,000
			Water Yield	6,000
			Evapotranspiration (Sur. Irrig. Crops)	
			Evapotranspiration (Phreato-phytes)	6,000
			Evaporation (Water Surface)	
			Subsurface Outflow	
			Total	70,000
Arbon	Precipitation	200,000	Evapotranspiration (Natural)	178,000
			Water Yield	22,000
			Evapotranspiration (Sur. Irrig. Crops)	
			Evapotranspiration (Phreato-phytes)	22,000
			Surface Outflow	
			Subsurface Outflow	
			Total	200,000

ground-water use rate to be 15 inches, the total ground-water use would be 6,000 ac-ft/yr. If the application efficiency averages 60 percent, the annual rate of pumpage would be 10,000 ac-ft/yr. This estimate of pumpage and water use indicates that 30 to 50% of the estimated recharge to the aquifers in the subarea is being intercepted and used in Idaho.

The aquifer is at present in a transient state because ground-water development has upset the long-term equilibrium established under native conditions, therefore, the present ground-water outflow to Utah can not be determined until pumping has continued for many years and a new equilibrium is established between recharge to and discharge from the aquifers.

Pocatello Valley Subarea – The water yield of Pocatello Valley is estimated to be 6,000 ac-ft/yr (table 10). Because the basin is closed to surface outflow, the water yield must be evaporated from the pond that forms in the valley bottom in wet years, increase the storage in the aquifer system, or leave the valley as subsurface flow. Based upon the preliminary estimates of size and volume of the pond collected by the SCS (Colsner, written communication, 1971), the following estimates of evaporation can be made:

Table 11

Estimate of Evaporation from the Flood Pond in the Pocatello Valley Subarea

Month	Monthly Evap. * (in.)	Pond Area At Start of Month (acres)	Average Pond Area During Month (acres)	Pond Area at End of Month (acres)	Evap. Volume (ac-ft)	Pond Volume at End of Month (ac-ft)
Jan.		-	-	1,300	-	950
Feb.	0.62	1,300	1,275	1,250	70	880
Mar.	1.34	1,250	1,225	1,200	120	760
April	2.39	1,200	1,100	1,000	210	550
May	3.49	1,000	800	700	250	300
Total	7.84	-	-	-	650	-

* Evaporation values are based upon those calculated by the USGS for the nearby Raft River Basin for a location at 5,000 feet with low to moderate winds (Walker and others, 1970, p. 41).

In addition to the 300 ac-ft/yr not evaporated from the pond, the quantity of water added by rainfall on the pond and runoff from adjacent land surfaces during the period for which the pond is assumed to exist must also percolate to the water table. Precipitation on the pond surface is estimated to be 400 ac-ft/yr during the normal February through May months. During an average year the pond is practically dissipated by late May; thus, this rapid rate of dissipation of the pond supports the theory that not all of the water yield is evaporated within the basin and a portion is leaving the basin as ground-water underflow.

Arbon Subarea – The water yield of the Arbon subarea is estimated to be 22,000 ac-ft/yr (table 10). Full or supplemental irrigation using surface water is practiced on about 1,700 acres. Acreage figures are based upon U. S. Agricultural Stabilization and Conservation Service (ASCS) aerial photographs of the subarea and upon recorded water rights. If an average of 15 inches of water is consumptively used by surface irrigated crops, water use would total 2,000 ac-ft/yr. Full or supplemental irrigation using ground water is practiced on approximately 800 acres. If the consumptive water use averages 15 inches, the actual outflow from the area will be reduced by about 1,000 ac-ft/yr when the aquifer system reaches a new equilibrium. Prior to irrigation pumpage, however, the outflow can be estimated to have been 17,000 ac-ft/yr surface outflow and 3,000 ac-ft/yr underflow.

The narrow width of the aquifer near the lower end of the subarea provides evidence to support the contention that the volume of underflow is not large. Assuming an aquifer width of 1 mile and hydraulic gradient of 30 ft/mile, the transmissibility of the aquifer would have to exceed 85,000 gpd/ft to transmit 3,000 ac-ft/yr. This transmissibility is within the range of values normally found for valley-fill aquifers.

WATER QUALITY

The quality of ground water in the study area is generally fair to poor. Fifteen water samples from wells were collected for this study and 23 samples were collected by the USGS for previous studies. Results of analyses of the ground-water samples collected for this study are presented in table 12. Field observations of specific electrical conductance and temperature were also made. One analysis of the quality of surface water (Deep Creek) was made by the USGS.

The specific electrical conductance of the ground and surface water of the area ranged from approximately 480 micromhos (mhos x 10^{-6}) (umhos) to 4,400 umhos (fig. 24). Water with E.C. values greater than 1,000 umhos is located primarily in southern Curlew Valley while water with values less than 1,000 umhos is present in the rest of the study area. The E.C. of water issuing from the Holbrook Springs area average 725 umhos, slightly lower than the ground water in upper Curlew Valley and much lower than that of the southern portion of the valley. This is possibly due to (1) a different source area for the water or, (2) a shorter distance of travel through materials containing residual salts. Data are not available at this time to determine if the springs are connected to a source area other than the valley fill. Values of E.C. increase in lower Curlew Valley. This is believed to be the result of (1) deeper wells which penetrate a greater thickness of sediment, and (2) a higher concentration of residual salts in the sediments left by a slowly receding Lake Bonneville. As Lake Bonneville receded, the lake water became highly concentrated with dissolved salts. Isolated depressions filled with these saline waters and, in time, formed lenses of evaporite minerals which continually enrich the ground water in this area.

Table 12

Results of Chemical Analyses of Ground Water Sampled in the Western Oneida County Study Area

Location	pH	EC x 10^6 at 25^o C	Temp. ^{o}F	Anions (ppm)				TDS	Cations (ppm)				SiO_2	F	As	SAR
				HCO_3 + CO_3	Cl	SO_4	NO_3	PPM	Ca	Mg	Na	K	PPM	PPM	PPM	
1. 10S 34E 7da1	7.72	1197	50	455	128	43	27.00	744	101	41	90	10.9	53.0	.35	.000	1.9
2. 11S 33E 12ab1	7.76	483	52	200	43	10	1.85	316	67	10	14	2.3	41.5	.17	.000	0.4
3. 11S 33E 23ba1	7.44	902	50	290	89	34	62.61	616	119	15	39	1.6	18.5	.07	.000	0.9
4. 13S 32E 30bc1	7.46	810	52	227	123	24	2.47	500	85	22	35	5.5	48.5	.23	.000	0.9
5. 13S 33E 16da1	7.54	934	50	261	135	37	22.93	628	102	23	42	7.0	48.5	.17	.000	1.2
6. 14S 30E 32bc1	7.44	587	58	234	54	21	.61	308	58	24	44	3.1	17.5	.11	.000	0.5
7. 14S 32E 36bd1	7.82	1392	52	357	250	41	3.71	796	113	45	85	13.3	42.5	.32	.000	1.9
8. 15S 30E 27ba1	7.68	801	58	203	120	29	13.01	572	69	38	17	7.8	57.0	.12	.000	0.4
9. 15S 32E 33ad1	7.50	1298	53	293	202	98	1.85	780	56	34	116	7.8	47.0	.25	.000	2.6
10. 15S 32E 36aa1	7.54	1038	66	250	178	31	2.47	616	38	23	94	15.6	66.5	.31	.000	2.5
11. 15S 33E 8cd1	7.87	935	55	251	145	32	3.09	584	29	18	92	8.6	51.5	.34	.001	2.6
12. 16S 32E 4ab1	7.44	1495	53	275	256	134	3.71	880	71	43	116	8.6	43.5	.23	.000	2.3
13. 16S 32E 16bb1	7.14	4392	52	231	1029	581	11.15	3352	255	154	296	19.5	41.0	.16	.000	3.2
14. 16S 32E 27da1	7.40	3101	51	391	246	994	10.53	2344	119	72	407	22.7	41.5	.97	.000	6.1
15. 15N 7W 30dd1 (Utah)	7.40	3768	54	277	909	236	4.33	2172	167	101	454	36.7	59.0	.97	.020	6.8
16. Upper Ireland Spring 14S 34E 15	7.6	780	60	211	123	25	20	503	80	18	46	3.0	22	0.1	.000	1.2
17. 16S 32E 26caa1		2020	52	325	380	172	2.0	1230	112	54	210	18	49	0.5	.000	4.0

Samples 1 through 15 obtained August 15, 1970 by Idaho Department of Water Administration.
Samples 16 and 17 obtained by U. S. Geologic Survey, Salt Lake City, August 1970.

The temperature of the ground water in the study area ranges from 48 to 66° F (fig. 24). No significant variations occur from subarea to subarea.

The chemical characteristics of the ground water vary with each subarea. Chemical analyses of 26 samples from the Curlew subarea indicate two major types of water, calcium bicarbonate and sodium bicarbonate. Seven of the samples indicate a high concentration of calcium or sodium chloride. The chemical data shown in table 12 are presented graphically in figure 25. These patterns, showing the relative concentration in percent of the six major ions in ground water, allow a visual comparison of ground-water quality. It is noted that the ionic variation is much greater in the southern portion of the Curlew subarea than in the rest of the study area.

Two major types of water appear to be present in the Pocatello Valley subarea. The six analyses that are available show that both calcium bicarbonate and calcium chloride water exist. The calcium and carbonate ions are believed to be derived from the limestone bordering the valley. The chloride ions are believed to be the result of the accumulation of water in the basin without surface outflow which tends to leach the soluble salts from the soil. This enriched water than percolates downward to the ground-water system.

Ground water in both the Arbon and Black Pine subareas is of the calcium bicarbonate type. This is to be expected because of the close proximity of the calcareous bedrock from which a portion of the recharge to the aquifer is derived.

Water from 10 of the 38 wells sampled does not meet U. S. Public Health Service drinking water standards (1962). The recommended maximum limits for some of the ions are listed below.

Constituent	**Recommended Maximum (ppm)**
Chloride (Cl)	250
Sulfate (SO_4)	250
Nitrate (NO_3)	44
Arsenic (As)	.05
Total Dissolved Solids (TDS)	1,000

Well 16S 32E 16bb1 exceeds the recommended limit for chloride, sulfate and total dissolved solids. Wells 14S 32E 36bd1 and 16S 32E 4ab1, all meet or exceed the recommended maximum for chloride contents; well 16S 32E 27da1 exceeds the limit for sulfate and total dissolved solids; wells 16S 32E 26caa1 and 15N 7W 30dd1 (Utah) exceed the recommended limit for chloride and total dissolved solids. The only excessive ion of concern is nitrate for which the recommended limit is 44 parts per million (ppm). Well 11S 33E 23ba1 contains 62.6 ppm of nitrate expressed as NO_3. Excessive nitrate in drinking water has been linked to cyanosis or "blue baby" disease in infants (Comly, 1945) whose feeding formulas are mixed

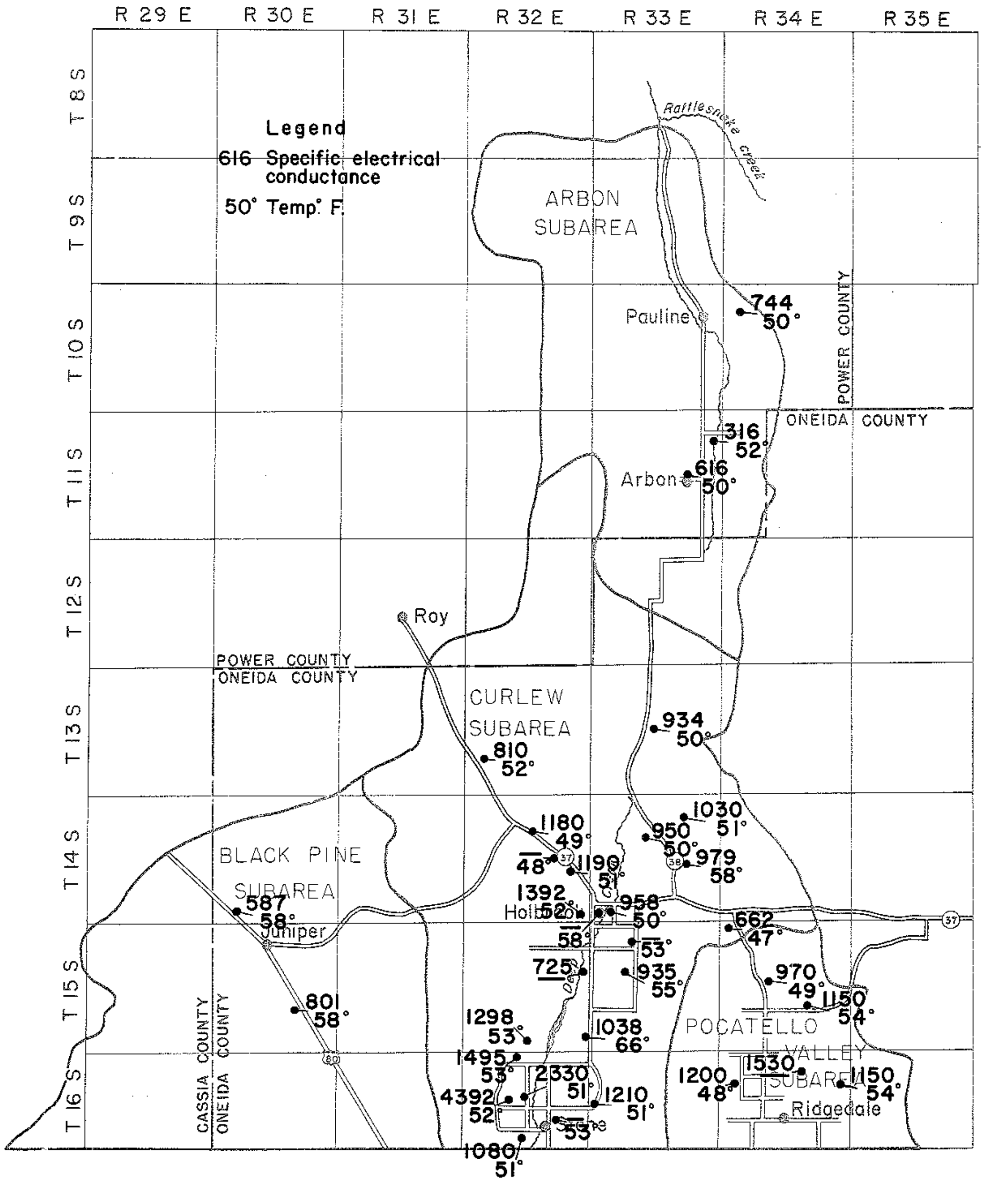

FIGURE 24. Specific electrical conductance and temperature of ground water in wells in the western Oneida County study area.

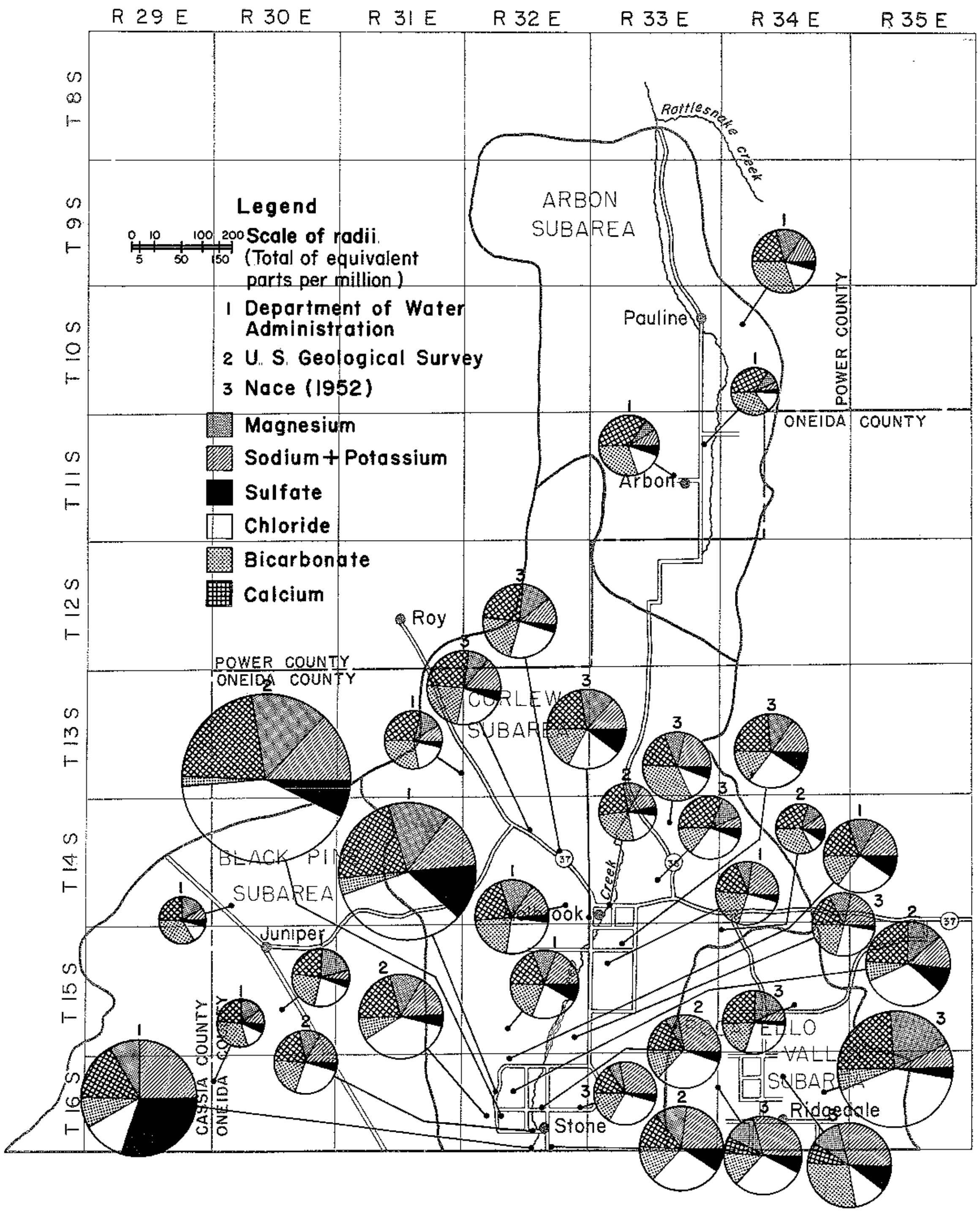

FIGURE 25. Percentage diagrams of water quality in the western Oneida County study area.

with these waters. Because of a reported occurrence of arsenic in wells in lower Curlew Valley, the samples collected for this investigation were analysed for this ion. As shown in table 12 the greatest concentration of arsenic found was in well 15N 7W 30dd1 (Utah). The 0.02 ppm concentration found in this well is below the maximum limit as set forth in the drinking water standards.

The classification of ground water for irrigation is shown by a plot of E.C. versus the sodium adsorption ratio (SAR) developed by the U. S. Salinity Laboratory staff (1954) (fig. 26). The SAR relates the percentage of sodium to calcium and magnesium as defined by the equation

$$\frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

wherein Na^{+}, Ca^{++}, and Mg^{++} refer to the concentrations of the designated soluble cations expressed in milliequivalents per liter.

All of the samples have a low sodium or alkali hazard as shown by figure 26. However, two of the samples have a medium salinity hazard and the rest have a high salinity hazard. Therefore, water from these wells would not be suitable for growing any but salt tolerant crops. Examples of these are: cereal grains, alfalfa, crested wheat grass, sugar beets, corn and potatoes.

WATER RIGHTS

The Idaho Department of Water Administration has active permits and licenses for development of 208 cfs of ground water and approximately 100 cfs of surface water (fig. 27). Most, if not all, of the surface water available during the irrigation season is under permit, license, or court decree.

It is estimated that 141 cfs of the 208 cfs of ground water filed on has been developed, leaving 67 cfs yet to be put to beneficial use.

Most of the filings for surface water in the study area were made prior to 1930. The greatest activity in filing for the right to develop ground water was in the period from 1950 to 1965.

POTENTIAL FOR WATER RESOURCE DEVELOPMENT

A potential for additional development exists in each subarea. This development could occur without significant adverse effect on the present Idaho water use because it is based upon full utilization of the water yield estimated for each subarea. Additional development in Black Pine and Curlew subareas may, however, have an effect on present use of water in Utah.

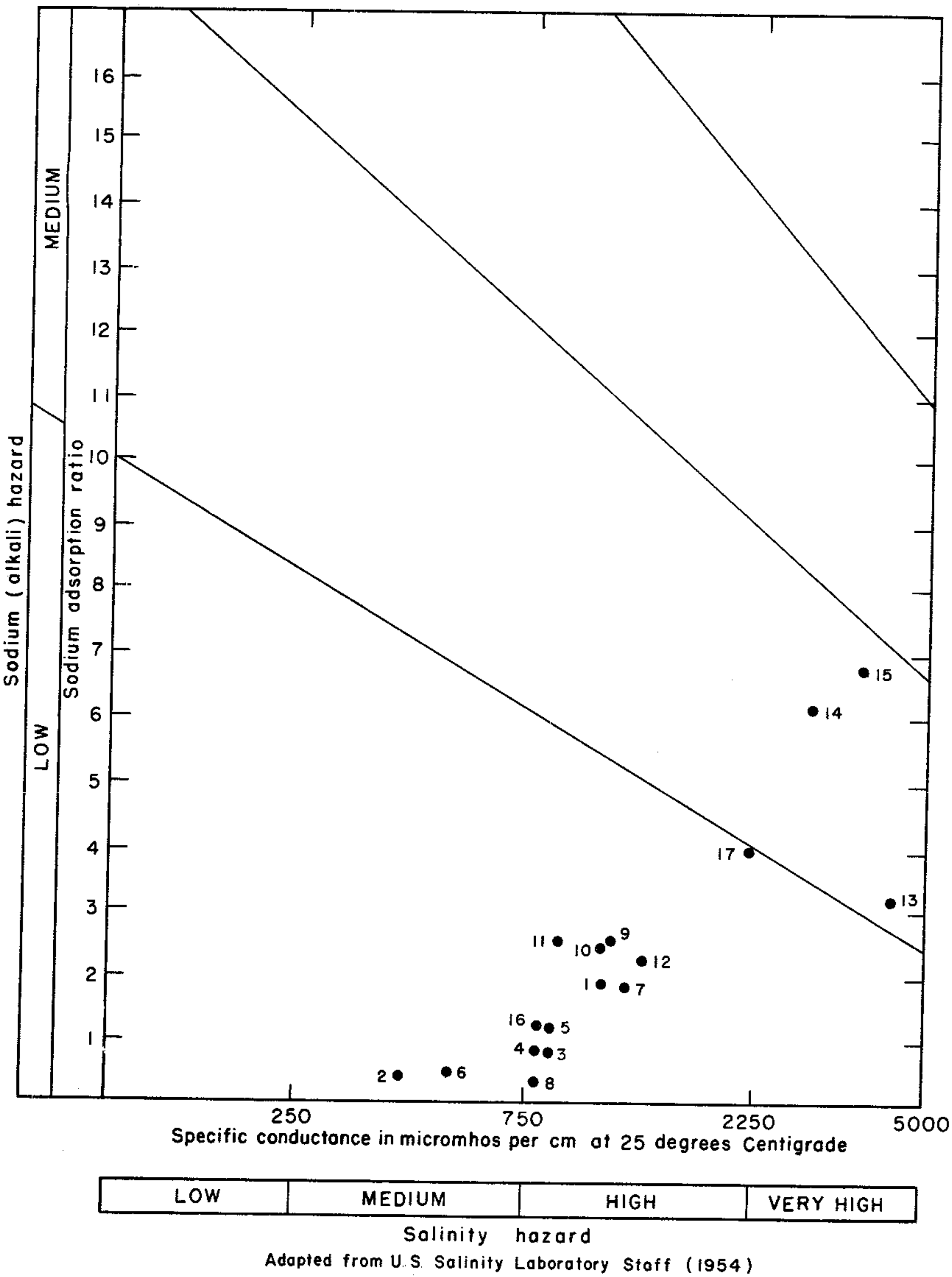

FIGURE 26. Classification of ground water for irrigation in the western Oneida County study area.

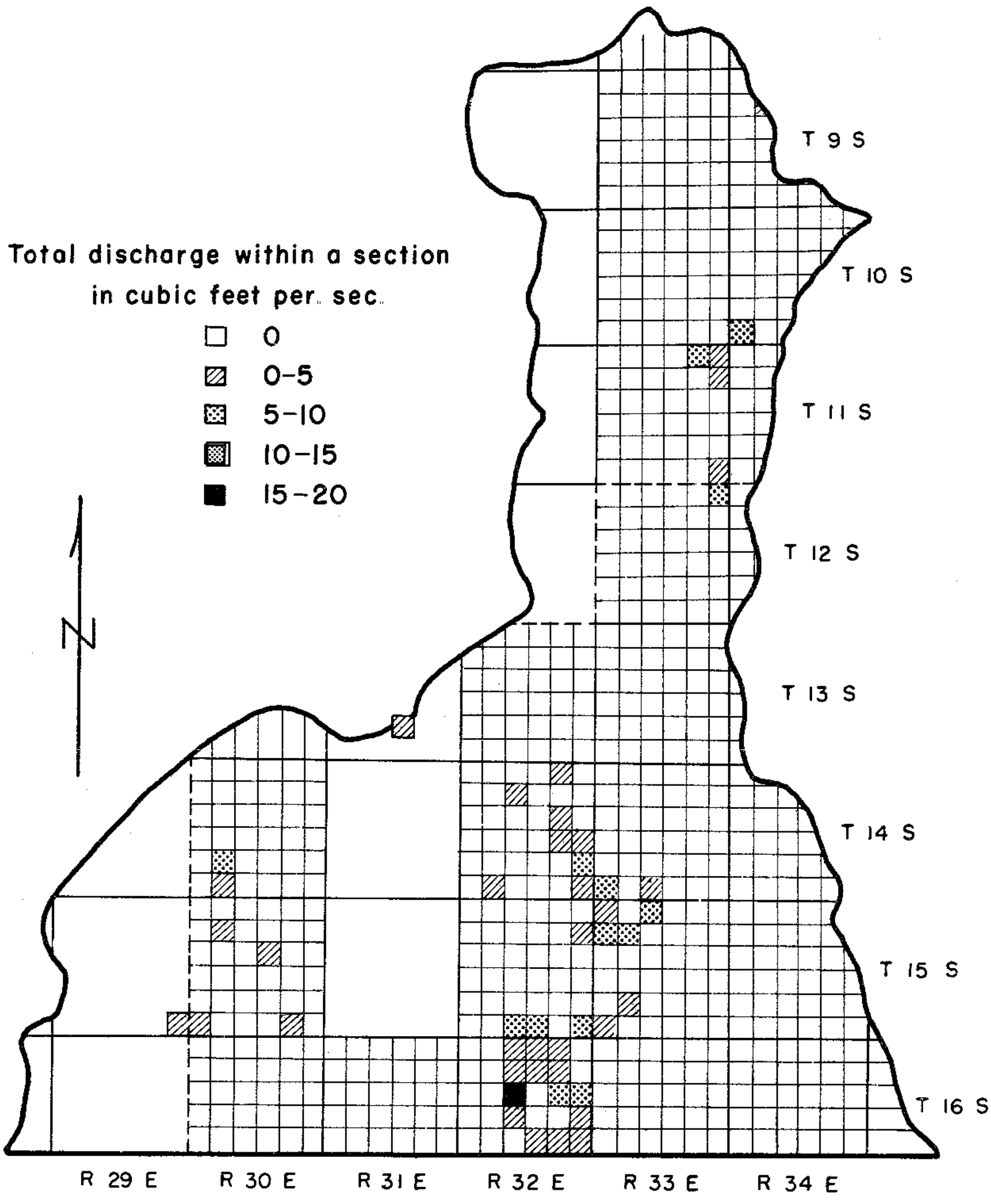

FIGURE 27. Distribution of water filings by section in western Oneida and southern Power counties.

The potential in the Black Pine subarea appears limited because of federal land ownership. The best land, which is presently under multiple-use classification, lies along the southern portion of the subarea just north of the Utah-Idaho state line where the ground-water levels are relatively uniform and less than 200 feet deep. The low-value crops now produced in the area make pumping lifts greater than 200 feet unreasonable, even for large land ownerships. If permeable geologic materials are encountered at this location as they are south of the border, high-yielding irrigation wells could be developed. This development, however, could have an adverse effect on water levels in the Utah portion of the valley if the amount of water withdrawn by both Idaho and Utah irrigators exceeds the water yield of the basin.

Potential development in the Pocatello Valley subarea appears to be limited to increased use of the surface-water resource. The flood pond, which forms during most years could be used to irrigate up to 10,000 acres once or twice per year, which could increase the grain crop significantly. A portion of the area normally covered by the pond could be excavated to decrease the area of the pond and increase the depth. This would decrease the amount of evaporation and increase the quantity of land available for farming during the spring months. The primary cost of such a project would be in excavation, installation of a pumping plant and a canal system.

The Arbon subarea has little potential for surface-water development beneficial to lands within the study area. However, a dam across Bannock Creek in sections 27 and 28, Township 8 South, Range 33 East, could have adequate capacity to store approximately 25,000 acre feet of water (U. S. Corps of Engineers, 1948). This would irrigate about 10,000 acres of presently arable land downstream within the boundaries of the Fort Hall Indian Reservation. The land inundated would largely be on the Indian reservation. Some potential exists for development of irrigation wells in the central portion of the valley. The data collected for this report indicates at least an additional 3,000 ac-ft/yr could be withdrawn without seriously altering ground-water levels. However, some detrimental effect may occur on the flow of Bannock Creek because of changes in ground-water inflow.

The greatest potential for development is in the Curlew subarea and is primarily from ground water. Approximately 13,000 acre feet of underflow leaves the valley each year. This could be salvaged by widely-spaced irrigation wells in the southern portion of the subarea. This quantity of water would irrigate approximately 2,500 acres of additional land or provide supplemental water to many times that amount. If such development were to occur, no significant lowering of the water table or effect on Holbrook Springs would be expected. Approximately 6,000 acre feet of water is escaping the subarea each year during the non-irrigation season from spring flow into Deep Creek and leakage around the dam at Curlew Valley Reservoir. This runoff could be salvaged by installation of a small dam and pumping station for utilization on the lands near the southern boundary of the subarea, subject to downstream water rights.

CONCLUSIONS AND RECOMMENDATIONS

The present water development in the western Oneida County study area does not exceed the available water supplies. Surface water supplies available during the irrigation season are fully appropriated either with the study area or by prior right holders in downstream areas. Some potential for additional development using surface water may exist if satisfactory storage sites can be developed to impound water that escapes from the area during the non-irrigation season. The effect of this development upon prior rights downstream must be evaluated before actual construction.

A potential for additional development of ground water in Black Pine, Curlew and Arbon subareas also exists; but, again, the effect of this development on prior water rights, particularly ground-water users in Utah, needs to be considered.

The following studies are recommended to more fully evaluate the water resource potential of the study area:

1. The relationship of Holbrook Springs to the regional ground-water system should be determined. A comparison of chemical constituents in the ground water might provide useful information on this relationship. The discharge of Holbrook Springs should be monitored continuously for a period of at least two years and compared to changes in ground-water levels in the Curlew subarea. A large ground-water development near the springs could possibly affect the discharge of the springs and surface-water right holders.

2. The distribution of irrigation wells for optimum utilization of the ground-water resource in Curlew and Black Pine subareas should be determined.

3. The relationship of soil chemistry to irrigation water chemistry should be evaluated to insure that the irrigation practices used are adequate to maintain soil tilth.

4. Feasibility studies of reservoir sites on Bannock and Deep Creek and of the utilization of the flood pond in Pocatello Valley subarea should be made.

5. It is also recommended that no restrictions on permit for water rights be initiated at this time for the western Oneida County study area.

REFERENCES

Anderson, A. L., 1931, Geology and mineral resources of eastern Cassia County, Idaho: Idaho Bur. of Mines and Geol. Bull. 14.

Bolke, E. L. and Price, Don, 1969, Hydrologic reconnaissance of Curlew Valley, Utah and Idaho: Utah Dept. of Natural Resources technical Pub. 25.

Bright, Robert C., 1963, Pleistocene lakes Thatcher and Bonneville, southeastern Idaho: Ph.D. Dissert., University of Minnesota.

Comly, H. H., 1945, Cyanosis in infants caused by nitrates in well water: Am. Med. Assoc., Jour., v. 129, No. 2, p. 112-116.

Nace, R. L., 1952, Record of wells and springs in western Oneida County, Idaho: U. S. Geol. Survey open file report.

Nace, R. L. and others, 1961, Water resources of the Raft River Basin, Idaho-Utah: U. S. Geol. Survey Water Supply Paper 1587.

Piper, A. M. 1924, Possibilities of petroleum in Power and Oneida counties, Idaho: Idaho Bur. of Mines and Geol. pamph. 12.

Pluhowski, E. J., 1970, Hydrology of the upper Malad River, southeastern Idaho: U. S. Geol. Survey Water Supply Paper 1888.

Theis, C. V., 1935, Relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Am. Geophys. Union Trans., pt. 2, p. 519-524; dupl. as U. S. Geol. Survey Ground Water note 5, 1952.

Thompson, D. G. and Faris, R. W., 1932, Preliminary report on water resources of Malad and Curlew valleys, Oneida County, Idaho: U. S. Geol Survey open file report

U. S. Army Corps of Engineers, 1948, Review report on Columbia River and tributaries, appendix G, Upper Snake River Basin: p. G-194-127.

U. S. Bureau of Reclamation and U. S. Army Corps of Engineers, 1952, The Columbia River: House Document 473, 81st Congress, second session, v. 1, p. 119-127.

U. S. Public Health Service, 1962, Drinking water standards: U. S. Public Health Service Pub. 956.

REFERENCES (Cont'd.)

U. S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of alkali soils: U. S. Dept. of Agriculture Handb. 60.

Walker, E. H., Dutcher, L. C., Decker, S. O., and Dyer, K. L., 1970, The Raft River Basin, Idaho-Utah, as of 1966: Idaho Dept. of Water Adm. Water Info. Bull. No. 19.

Young, N. C. and Ralston, D. R., 1971, Reasonable pumping lifts for Idaho: Idaho Dept. of Water Adm. Water Information Bulletin No. 21.

B A S I C D A T A

WELL NUMBER	OWNERSHIP	ALTITUDE OF LSD (feet)	YEAR DRILLED	USE OF WELL	DEPTH OF WELL (feet)	DEPTH CASED (feet)	DIAMETER OF WELL (inches)	DEPTH TO WATER (feet)	DATED MEASURED	LIFT TYPE	POWER (hp)	YIELD OF WELL (gpm)	DRAWDOWN (feet)
CURLEW SUBAREA													
13S 32E 21bc	Private	---	1954	Domestic	300	219	6	180	7-10-54	----	---	300	20
13S 33E 4aa	Private	---	1969	Domestic	105	100	10	38	6-25-69	----	---	---	none
14S 32E 25bd	Private	48,003	1966	Irrigation	107	107	14	11	6-26-70	----	---	600	52
14S 33E 31ac	Private	---	1967	Irrigation	95	84	14	2	4-10-70	Electric Turbine	30	520	65
15S 32E 33db	Company	4,620	1968	Irrigation	402	402	20	55	4-07-70	Electric Turbine	200	2,700	237
15S 32E 36aa	Private	4,672	1960	Irrigation and Stock	230	230	18	82	4-08-70	Electric Turbine	---	1,700	116
15S 33E 8ca	Private	---	1954	Irrigation	280	259	14	20	5-00-54	----	---	2,000	135
16S 32E 7da	B.L.M.	---	1965	Stock	485	485	8	420	10-00-65	----	---	8	5
16S 32E 16ba	Private	4,576	1968	Domestic	100	100	8	30	9-00-68	----	---	---	---
16S 32E 25ad	Private	4,719	1958	Irrigation	201	200	16	84	4-10-70	Electric Turbine	100	2,500	25
16S 33E 18bb	Private	---	1969	Domestic	64	·60	10	7	3-00-69	----	---	---	25
ARBON SUBAREA													
10S 34E 7da	Private	5,034	1961	Irrigation	170	40	16	8	10-00-61	----	---	450	80
10S 34E 31cc	Private	5,082	1962	Irrigation	180	175	16	artesian	11-00-62	----	---	3,400	130
11S 33E 2ab	Company	---	1926	Oil	3,855	1,030	12	---	----	none	none	none	none
11S 33E 23ab	Private	5,164	1969	Domestic	90	90	10	28	6-19-70	----	---	---	---
BLACK PINE SUBAREA													
14S 30E 32cd	Company	---	1966	Irrigation	200	200	20	115	8-17-66	----	---	80	0
15S 30E 15bb	Company	---	1951	Domestic & Fire Prot.	540	535	16	265	6-00-51	----	---	50	10
15S 30E 35da	State of Idaho	---	1967	Domestic	505	505	10	302	9-00-67	Electric Submersible	10	60	6

CURLEW SUBAREA

WELL NUMBER 13S 32E 21bc
Aquifer -- gravel

	Depth to Bottom of Unit	Thickness of Unit
Top soil	3	3
Brown clay	79	76
Water in gravel	81	2
Sand and rock	103	22
Rocky clay	219	116
Mountain rock	292	73
Water in gravel	300	8

WELL NUMBER 13S 33E 4aa
Aquifer -- sand and gravel

	Depth to Bottom of Unit	Thickness of Unit
Top soil	2	2
Packed gravel, coarse	21	19
Loose gravel	24	3
Cemented gravel	26	2
Sand and gravel, yellow color	55	29
Soft and sandy	57	2
Yellow clay and gravel	72	15
Soft and sandy	75	3
Sandy clay	99	24
Soft	101	2
Packed sand	105	4

WELL NUMBER 14S 32E 25bd
Aquifer -- gravel

	Depth to Bottom of Unit	Thickness of Unit
Soil	3	3
Clay	7	4
Gravel; water bearing	10	3
Clay	13	3
Blue clay	52	39
Gravel; water bearing	58	6
Gravel; water bearing	65	7
Clay, yellow	76	11
Gravel; water bearing	83	7
Clay, sandy	88	5
Gravel; water bearing	92	4
Clay	94	2
Gravel; water bearing	98	4
Very sandy clay	107	9

WELL NUMBER 14S 33E 31ac
Aquifer -- gravel

	Depth to Bottom of Unit	Thickness of Unit
Soil	1	1
Gravelly soil	17	16
Blue clay	63	46
Gravel; water bearing	84	21
Blue clay	95	11

WELL NUMBER 15S 32E 33db
Aquifer -- sandstone

	Depth to Bottom of Unit	Thickness of Unit
Top soil and clay	15	14
Clay	25	10
Gravel	40	15
Clay	50	10
Gravel; water bearing	65	15
Clay	70	5
Gravel	80	10
Clay, brown	90	10
Gravel	95	5
Clay	105	10
Sandstone	110	5
Clay	120	10
Gravel	125	5
Clay	135	10

WELL NUMBER 15S 32E 33db (cont'd.)

	Depth to Bottom of Unit	Thickness of Unit
Sandstone	145	10
Gravel	150	5
Sandstone	155	5
Gravel	160	5
Clay	180	20
Sticky clay	230	50
Sandstone	240	10
Sand and gravel	245	5
Clay	272	27
Sandstone	280	8
Sandy	290	10
Sandstone	300	10
Clay	310	10
Sandy clay	320	10
Sand and clay	325	5
Blue clay	340	15
Black clay	355	15
Pea gravel and sand	360	5
Blue clay	370	10
Gravel and sand	375	5
Hard sandstone	385	10
Sandy, brown	395	10
Sandstone	400	5

WELL NUMBER 15S 32E 36aa
Aquifer -- sandstone

	Depth to Bottom of Unit	Thickness of Unit
Top soil	1.5	1.5
Clay	96	94.5
Gravel; water bearing	106	10
Sandstone; water bearing	118	12
Clay	119	1
Sandstone; water bearing	126	7
Clay	128	2
Sandstone; water bearing	135	7
Clay	136	1
Sandstone	151	15
Clay	152	1
Sandstone; water bearing	183	31
Clay	184	1
Sandstone; water bearing	192	8
Clay	194	2
Sandstone; water bearing	229	35
Clay	230	1
Sandstone; water bearing	270	40
Red sand and clay; water bearing	272	2
Sandstone; water bearing	310	38
Clay	312	2
Sandstone	319	7
Clay	320	1
Sandstone	325	5
Clay	327	2
Sandstone	331	4

WELL NUMBER 15S 33E 8ca
Aquifer -- gravel

	Depth to Bottom of Unit	Thickness of Unit
Soil	2	2
Clay, brown	15	13
Sand, brown	30	15
Clay, brown	35	5
Clay, blue	120	85
Gravelly clay, blue; water bearing	131	11
Clay, yellow	137	6
Gravel; water bearing	142	5
Clay	146	4
Gravel; water bearing	232	86
Clay, yellow	248	16
Clay, brown	251	3
Gravelly clay, brown	256	5

Well Number 15S 33E 8ca (cont'd.)

	Depth to Bottom of Unit	Thickness of Unit
Clay, yellow	268	12
Clay, red	275	7
Clay, white	280	5

WELL NUMBER 16S 32E 7da
Aquifer -- limestone and clay

	Depth to Bottom of Unit	Thickness of Unit
Clay and gravel	90	85
Rock -- limestone	100	10
Clay	115	15
Rock -- limestone	120	5
Clay and gravel	195	75
Rock	255	60
Limestone	295	40
Limestone	335	40
Limestone and clay; water bearing	428	93
Clay and limestone; water bearing	485	57

WELL NUMBER 16S 32E 16ba
Aquifer -- sand and gravel

	Depth to Bottom of Unit	Thickness of Unit
Top soil	3	3
Clay	30	27
Sand and pea gravel; water bearing	40	10
Clay	70	30
Sandstone	71	1
Clay	80	9
Sandstone	81	1
Sand and clay, some water	88	7
Sandstone	90	2
Sand and clay	100	10

WELL NUMBER 16S 32E 25ad
Aquifer -- gravel and sand

	Depth to Bottom of Unit	Thickness of Unit
Top soil	2	2
Sand	6	4
Cobble rock	7	1
Sandy clay	20	13
Sand	28	8
Clay	47	19
Clay and gravel	49	2
Gravel	50	1
Clay	60	10
Clay and gravel	64	4
Clay, gravel and boulders	79	15
Clay	86	7
Clay, gravel; water bearing	96	10
Gravel; water bearing	99	3
Gravel and sand; water bearing	104	5
Gravel and boulders; water bearing	110	6
Coarse gravel and some sand; water bearing	127	17
Boulders and sandy clay	164	37
Coarse gravel and some sand; water bearing	181	17
Coarse gravel and clay	199	18
Boulders; water bearing	201	2

WELL NUMBER 16S 33E 18bb
Aquifer -- gravel and clay

	Depth to Bottom of Unit	Thickness of Unit
Top soil	5	4
Brown clay	10	5
Yellow clay and sandy	20	10
Gravel	24	4
Yellow clay	35	11
Imbedded gravel	40	5
Rusty clay and gravel	48	8
Brown clay and gravel	55	7
Gray clay	61	6

ARBON SUBAREA

	Depth to Bottom of Unit	Thickness of Unit
WELL NUMBER 10S 34E 7da		
Aquifer -- gravel and sandstone		
Soil	5	5
Sandstone	20	15
Gravel; water bearing	40	20
Sandstone	78	38
Brown clay	85	7
Rocks in cement formation	105	20
Sandstone; water bearing	170	65
WELL NUMBER 10S 34E 31cc		
Aquifer -- gravel		
Black soil	16	16
Fine gravel with some water	20	4
Brown clay	70	50
Good gravel with flowing water started at 75 feet deep	175	105
WELL NUMBER 11S 33E 2ab		

Surface soil	80	80
Clay and gravel	190	110
Gravel and silt	550	360
Lime rock	553	3
Clay, light green	590	37
Clay, white	620	30
Clay, brown	660	40
Clay, white	690	30
Clay, chocolate	720	30
Dark lime rock	725	5
Clay, dark green	800	75
Gravel, gray	810	10

	Depth to Bottom of Unit	Thickness of Unit
Clay, blue	820	10
Gravel, reddish	825	5
Clay, green pea cast	865	40
Sand, pink cast	875	10
Shale, green	915	40
Shale, reddish cast	930	15
Shale, quite red	950	20
Shale, light red	955	5
Red lime	960	5
Mud	965	5
Sand, gray	985	20
Mud	987	2
Sand, gray	995	8
Gravel, gray	1030	35
Gravel, red and white	1070	40
Broken lime	1080	10
Sand, light brown	1140	60
Lime shells	1190	50
Sandy lime	1235	45
White, sticky	1255	20
Shale, broken and limey	1340	85
Shale and lime shells	1365	25
Sand, dark brown	1377	12
??	1390	13
Shale and sandy lime	1410	20
Sand, dark brown	1422	12
Shale and sandy lime	1437	15
Sand, dark brown	1440	3
Lime	1530	90
Sandy lime	1705	175
Sand	1712	7
Brown shale	1722	10
Sandy lime	1930	208
Lime	1955	25
Sandy lime	2025	70

Well Number 11S 33E 2ab (cont'd.)

	Depth to Bottom of Unit	Thickness of Unit
Porous sand with water	2045	20
Sandy lime	2141	96
Narrow shelves of lime with thin bedded sandstone and shale between	2176	35
Sandy lime	2188	12
Dark brown, hard lime	2204	16
Narrow biffons of lime shale and sandstone between	2221	17
Sandy lime	2330	109
Sandy lime with pebbles	2440	110
Gray lime, hard	2475	35
Gray sand	2484	9
Hard gray lime and shale	2485	1
White sand and shale	2508	23
Yellow brown sand	2530	22
Hard shale and white lime	2532	2
Sharp gray and black sandstone lime	2538	6
Brown lime and sand	2558	20
Brown shale with lime	2570	12
Blue shale with sand	2575	5
Yellowish brown sand	2580	5
Sand, shell shale	2590	10
Clay, sand and river waste	2620	30
Blue-brown sand and shale	2630	10
Light gray shale, smooth	2640	10
Light gray shale with sand and gravel	2645	5
Blue hard shale	2650	5
Blue-brown sand and shale	2652	2
Light gray sand with gravel	2656	4
Hard sand, gray and black	2660	4
Clay and sand, blue and yellow	2662	2
Blue gray sand and gravel	2665	3
Light gray sand	2671	6
Blue-brown shale	2676	5
Decomposed lime and shale, brown	2683	7
Blue-brown shale and sand	2691	8
Light brown sand and shale	2698	7
Chocolate shale	2703	5
Gray lime cap, hard	2707	4
Yellow clay and shale	2712	5
Yellow sand and shale	2715	3
Brown shale and sand	2728	13
Brown sand, lime, shale	2738	10
Gray shale and sand	2745	7
Brown lime and shale	2750	5
Hard brown lime and shale	2752	2
Brown muck, soft	2767	15
Decomposed lime and shale, brown	2770	3
Hard limish cap	2775	5
Dark brown shale	3016	241
Dark gray shale	3384	368
Light gray shale	3488	104
Dark gray shale	3855	367

WELL NUMBER 11S 33E 23ab

Aquifer -- gravel

	Depth to Bottom of Unit	Thickness of Unit
Soil	5	5
Clay	13	8
Gravel	20	7
Clay	28	8
Gravel; water bearing	34	6
Clay	38	4
Gravel; water bearing	47	9
Clay	84	37
Gravel; water bearing	90	6

BLACK PINE SUBAREA

WELL NUMBER 14S 30E 32cd
Aquifer -- limestone and gravel

	Depth to Bottom of Unit	Thickness of Unit
Soil	2	2
Gray clay, gravel	19	17
Gravel and some clay	47	28
Gray clay with some gravel; water bearing	124	77
Hard gray limestone	127	3
Softer gray rock; water bearing	131	4
Hard gray rock (limestone)	133	2
Gray limestone rock; water bearing	202	69

WELL NUMBER 15S 30E 15bb
Aquifer -- gravel

	Depth to Bottom of Unit	Thickness of Unit
Top soil	4	4
Light brown clay and gravel	25	21
Sand and gravel	70	45
Yellow clay and gravel	75	5
Brown sandy clay	80	5
Brown clay and gravel	90	10
Yellow clay and gravel	267	177
Small gravel; water bearing	268	1
Yellow clay and gravel	275	7
Small gravel; water bearing	280	5
Fine sand and gravel	285	5
Sand and gravel conglomerate	400	115
Fine gravel conglomerate	410	10
Fine gravel and sand conglomerate	430	20
Fine gravel conglomerate	443	13
Sandy clay with gravel	458	15
Clay and gravel	525	67
Fine gravel; water bearing	540	15

WELL NUMBER 15S 30E 35da
Aquifer -- gravel

	Depth to Bottom of Unit	Thickness of Unit
Sand	16	16
Tan clay	47	31
Tan clay and gravel	83	36
Tan clay	102	19
Tan clay and gravel	150	48
Brown clay and gravel	246	96
Brown clay	342	96
Brown clay and gravel	373	31
Tan clay and gravel	384	11
More gravel than clay; water bearing	386	2
Brown clay and gravel	395	9
Tan clay and gravel	415	20
More gravel than clay; water bearing	428	13
Brown clay	469	41
Tan clay and gravel, more gravel than clay; water bearing	474	5
Brown clay	505	31